THE SECOND BIENNIAL REPORT

OF THE DIRECTOR OF THE

Agricultural College Survey

of North Dakota

TO THE

Governor of North Dakota

ADMINISTRATIVE REPORT AND ACCOMPANYING PAPERS FOR THE YEARS

1903-4

DANIEL E. WILLARD

Director

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To Hon. Frank White, Governor of North Dakota, and the Honorable, the Governing Board of the Agricultural College Survey of North Dakota:

SIRS: I have the honor to present herewith the second biennial report and accompanying papers of the Agricultural College Survey of North Dakota, including the work of administration and the field operation for the biennial period of Nineteen Hundred and Three and Nineteen Hundred and Four. My connection with the Survey as director dates from the first day of April, Nineteen Hundred and Three, on which day the duties of instructor in the Agricultural College were assumed, and therewith, as required by the law organizing the Survey, the duties of Director of the Agricultural College Survey of the State.

The organization and administration of the Survey had been so well done by my lamented predecessor, the late Professor Charles H. Hall, that the successful progress and carrying forward of the work seemed but to require the continuation of the plans which had been outlined and the carrying on of the work which had been begun.

As agriculture is now and seems destined by Nature to be an industry of unequalled importance in this state the vital value and importance of a survey having the varied phases and departments of agriculture for its aim and purpose would seem to be apparent. Recognizing the importance of a scientific study of those subjects most fundamentally connected with agriculture, the Seventh Legislative Assembly authorized such a survey, and by the provisions of the act of organization constituted you its guardians and sponsors. Acting under your authority, therefore, I present you herewith a report which attempts to show what work has been undertaken, and the needs of the survey in order that its usefulness may be enhanced and realized.

Your honorable attention is respectfully called to the great discrepancy between the amount appropriated by the state for this

co-operative survey and that expended by the federal government for surveys within the limits of the state, the latter being fully five times the amount of the former. Attention is thus particularly directed to this fact because it has been adopted as the working policy of the general government to expend money for surveys in those states where money is also furnished for such surveys by the state, and it is the policy to expend an amount equal to that expended by the state. It is therefore obvious that it is greatly to the financial interest of the state to meet the cordial co-operation offered by the federal government with a fair consideration. In the following pages of the administrative report the needs of the different divisions represented by the survey are set forth, and a careful consideration of the facts is earnestly requested.

Very respectfully yours,

DANIEL E. WILLARD,

Director.

ADMINISTRATIVE REPORT

THE SECOND BIENNIAL REPORT

OF THE

AGRICULTURAL COLLEGE SURVEY

OF NORTH DAKOTA

BY DANIEL E. WILLARD, DIRECTOR.

Plan and Purpose of the Survey.—The purpose of the Agricultural College Survey is indicated by the title of the law organizing the survey, viz: "An act authorizing the board of trustees of the North Dakota Agricultural College to co-operate with the United States Federal Surveys, organized under the department of the interior of the United States, in completing a topographic, agricultural and geological survey as related to agriculture, together with an economic map of North Dakota, and making an appropriation therefor."

In a state in which the welfare of so great a percentage of its citizens is directly related to agriculture it is of the greatest importance that every avenue leading to the more perfect development of the resources of soil and water supply should be followed up. The Agricultural College and Experiment Station is a natural center from which many important investigations, touching upon the various phases of agriculture, would take their origin. The relations of the structure of the earth below the surface to the water supply and the rock-character of the soils to crop production are such that the investigations of the biologic, chemical and agricultural divisions of the experiment station must necessarily be intimately associated with the work of a geological survey.

Organization and Working Methods.—While in its character the Agricultural College Survey is co-operative with the United States Federal Surveys, yet it is independent in the management of its finances. For all expenditures for subsistence in the field, salaries for services or the purchase of materials sub-vouchers are taken, following the very accurate and perfect system employed by the United

States Geological Survey in the management of its field expenses. An itemized statement of all expenditures is made at intervals to the auditing member of your honorable board.

In the management of expenses incurred in connection with the federal surveys no accounting is made to the state, but is made directly to the federal authorities at Washington. In the conduct of the topographic surveys, the soil survey and the areal geology and under-ground water investigations all expenses are paid directly from Washington, except in the case of assistants on the soil surveys who are sent and paid by the state.

The Death of Professor Hall.—The untimely death of the late Professor Charles M. Hall, under whose direction the Agricultural College Survey was organized, was a great loss to the Agricultural College and the state. However the work of the Survey had been so well organized and the plans for the work so systematically made that it was possible for the work to be taken up with the least possible delay and loss.

The writer assumed charge of the work of the Survey on April 1, 1903. At this season of the year the summer's campaign of field operations is about beginning, and therefore it was necessary to enter at once upon the preparation of plans for active work in the field. No funds were available for the work at this time, as the appropriation for the present biennial period did not become available till July 1st of that year. However, funds were advanced by friends of the college, so that active preparations for work in the field were at once begun.

Field Operations, Season of 1903.—During the summer of 1903 field operations were conducted under four divisions, viz., soil survey, topographic survey, areal geology and underground waters, and a survey of the coteaus of the Missouri. The character of these surveys is shown in the accompanying detailed reports of field operations. They are briefly mentioned here as follows:

Sail Survey.—Mr. Thomas A. Caine and Mr. A. E. Kocher, trained soil specialists, were sent by Hon. Milton Whitney, chief of the bureau of soils, Washington, to make a detailed study of the soils in such part of the state as should be desired by the geological department of the college. The territory selected was a belt, two townships in width, extending from the Red River of the North at Fargo westward to the highland adjoining the Red River valley at

Buffalo, and the same two tiers of townships from the Sheyenne river at Valley City westward to the highland of the Missouri plateau west of Jamestown. This belt, extending as it does across nearly one-third of the width of the state, crosses every important type of soil in this portion of the state. The soil types in North Dakota lie generally in tracts extending north and south. Thus this east-and-west belt crosses nearly all the types, among which types may be noted from east to west the following: The fine silt-like 'gumbo' soils near the Red River of the North; the exceedingly fertile and level lake bottom soils from the Sheyenne river to Casselton and westward; the alternating sandy ridges and depressions about Wheatland, and the rolling prairies to the westward; at Valley City the bottom lands and terraces of the Sheyenne valley; the well-defined morainic hills with interspersed alkaline lakes and glacial drainage channels, between the valleys of the Sheyenne and the James rivers; the James valley sands and gravels; and the high plateau lands west of Jamestown.

Mr. Caine spent the entire season from April till October studying the soils of this region and preparing a map of the same. Mr. Kocher was engaged in the state during three months, from July till October. The report by Mr. Caine will soon be published by the Department of Agriculture, together with a colored map showing the different soil types. Through the kindness of Mr. Whitney, chief of the bureau of soils, advance proof sheets of Mr. Caine's report have been furnished for this report, and it is given with the accompanying papers.

During the first half of the season the state furnished an assistant to Mr. Caine, the salary and expenses of this assistant being the only expense to the state incurred in this survey.

Areal Geology and Underground Waters.—In co-operation with the United States Geological Survey, Division of Hydrography, important progress has been made in the preparation of a geologic map of the state and the determination of the underground water resources. This is thought to be one of the most valuable lines of research that has been undertaken, its results the most important and far reaching.

The significance of the geology of the surface of the earth as determining the fertility and value of the soil is coming to be more fully recognized each year as investigations of this character are

carried on in different parts of the United States. It is only possible to present with this report an incomplete description of the results that have been accomplished in this state in these investigations. The results are being elaborated and will be published with full descriptive text and colored maps in folios of the United States Geological Survey. Portions of the text of the Fargo-Casselton folio, now in press at Washington, are by permission of the authorities of the federal surveys included in the accompanying papers of this report. Some of the results also of the underground water investigations in the territory embracing all or portions of the counties of Cass, Barnes, Stutsman, Richland, Ransom, Sargent, LaMoure and Dickey are included in the accompanying report.

Topographic Survey.—During the summer of 1903 a survey was made by the United States Geological Survey for the purpose of establishing primary control preparatory to the detailed topographic survey on the two quadrangles lying north of the Fargo and Casselton quadrangles. The completed topographic map of these areas will be made another season. After the topographic survey has been completed the areal geology and underground water investigations will follow.

Survey of the Coteaus of the Missouri.—The Agricultural Survey has undertaken the completion of an important bit of mapping in the western portion of the state in the region known as the coteaus of the Missouri.

The coteaus are really glacial, or morainic, hills, and constitute the outer of the series of terminal moraines which were formed at the edge of the great ice sheet during the closing stages of the glacial period. The hills in this region form a portion of a vast system which extends from far north and west in Canada in a southwesterly direction across North Dakota and South Dakota, thence in a generally easterly direction across the continent to the Atlantic ocean.

No accurate map of that portion of this great moraine lying in North Dakota north and west of the main line of the Northern Pacific railway between Jamestown and Bismarck to the international boundary at the northwest corner of the state has ever been made. More or less detailed and complete maps of this great moraine have been made in other states, but not before in North Dakota.

This region embraces one of the great grazing domains of the state. The system of morainic hills and attendant deposits within the state embrace an unmapped tract varying from twenty to fifty miles in width and 200 miles in length. This region has within the past few years been in part occupied by settlers who desire to pursue general farming. A large part of this great tract is still open to homestead entry. Considerable tracts of these lands are better adapted to grazing than to general farming.

The survey had a twofold purpose in undertaking the preparation of an agricultural-geological map of this portion of the state. First, it was deemed of great importance to the state that the character and adaptability of these lands to farming and grazing should be made known, for the benefit of homeseekers and in the general interest of the development of the resources of the state. Second, it seems highly desirable that a map of the portion of the great continental moraine lying within the territory of North Dakota should be systematically and correctly mapped. All other portions of this great moraine have been mapped, from the Missouri river in South Dakota to the Atlantic ocean. Accordingly what has been called an agricultural-geological survey has been undertaken, and a party consisting of four men was placed in the field in July, 1903. Minot was the railroad point from which operations were conducted, and a field camp was first established about thirty miles south by southwest of Minot, in township 152, range 84. The party consisted of the director, two assistant geologists, a soil specialist, and for a part of the time a biologist, who gave attention to the native grasses of the region. A map showing the area surveyed and a descriptive report of the investigations made will be found with the accompanying papers of this report.

Biological Survey.—A biological survey of the state was contemplated in the organization of the Agricultural College Survey, the purpose being to make a thorough and systematic study of the native grasses and other useful and injurious plants, and to determine as far as practicable the value and detriment respectively of these. The study of the native plants gives a key to the cultivated varieties that can be best grown under given conditions of soil and climate. The plants of any region are so intimately associated with the soil and other geologic conditions that a biological survey and a geological survey naturally supplement each other.

The limited funds available for the work of the Survey has rendered it impracticable to do anything more than the merest preliminary work looking toward the ultimate completion of the biologic division of the economic map of the state.

Progress in the Division of Chemistry.—Owing to the limited finances it is possible to report only a comparatively small amount of progress made in the chemical investigations of the waters and the soils of the state in proportion to what the importance of the subject demands. What has been accomplished has been through the chemical laboratories of the college and by those regularly engaged in chemical work, under the direction of Professor E. F. Ladd. Owing to the large demands upon Professor Ladd's time for other chemical investigations and to the crowded condition of the college laboratories, it has been impracticable to attempt the systematic classification and analysis of soils and waters that had been contemplated.

FIELD OPERATIONS, 1904.

Soil Survey.—During the season of 1904 a very thorough and detailed soil survey was made in southern Towner county, Cando being headquarters for the party. Two experts were sent from the Department of Agriculture, bureau of soils, on July 1st, and they spent the months of July, August and September in this field. Another survey was made in Ward county, near Minot, by a soil student from the college. Reports of these surveys accompany the present report.

The survey in Towner county was conducted by Mr. E. O. Fippin and Mr. J. L. Burgess, trained soil specialists. In order to facilitate the work and give the state the largest possible benefit of the liberal treatment extended by the federal authorities, two assistants were sent from the college, thus making it possible to extend the investigations over a larger territory than would otherwise have been possible. Two parties or sections were organized for the conduct of the field work, a specialist and an assistant constituting each party.

The only expense incurred on the part of the state for this work was the salary and expenses of the two assistants, all expenses for livery services for both parties being borne by the bureau at Washington.

A survey covering an area of two townships situated near Minot in Ward county was made by Mr. Rex E. Willard. This survey was undertaken because of the importance of this region as a newly-developed agricultural region. The territory selected lies in part on the bottom of the ancient glacial Lake Souris and in part on the higher land which bordered the lake on the west.

Areal Geology and Underground Waters.—During the summer of 1904 the investigations which were in progress during the preceding season were continued under the auspices of the Division of Hydrography, United States Geological Survey. The detailed study of the Eckelson quadrangle, lying between Valley City and Jamestown, was carried on by the writer and Mr. H. V. Hibbard. A full report, including colored maps and descriptive text, will be published by the United States Geological Survey as a folio.

Survey of the Coteau of the Missouri.—The survey in the coteau region, commenced in 1903, was continued in 1904, as much being done as the funds available would allow. It was necessary to discontinue the work in this field before the close of the seaosn owing to the fact that the funds had been exhausted.

During the seasons of 1893-4 an extent of territory embracing about sixty townships has been mapped, and a map of the region traversed, and a descriptive report on the character of the lands accompanies this report.

Topographic Survey.—A topographic surveying party was sent from Washington, which was engaged the entire summer in the preparation of a topographic sheet embracing portions of Richland, Ransom and Sargent counties, and known as the Wyndmere sheet or quadrangle. The entire expense of this work was borne by the federal government, the state survey having so meager an amount to offer for co-operation that it was declined and the entire expense borne as above mentioned.

It may be proper to explain here that it is the policy of the federal government to expend each year in such surveys an amount equal to that appropriated for this purpose by the states. It will thus be apparent that if this work is to be continued in our state it will be needful to offer a sum for co-operation comparable to that offered for such work by other states.

A word regarding the character of the topographic survey and the areas that have already been surveyed may not be out of place

here. First, the topographic survey forms the basis for all further detailed surveys. The progress of all systematic work in the state will therefore be determined by the attitude that is assumed in regard to topographic work. If the state offers liberal co-operation in these surveys, this will render possible the more rapid advancement of the work along more strictly geological and economic lines. Moreover, the interest shown in the progress of the work by the state itself lends encouragement to the federal government that will naturally lead to continued co-operation in the surveys which have been already begun, and for the conduct of which the federal surveys have expended so liberal sums.

A topographic map or sheet covers an area of one-fourth of a degree of the earth's surface, a quadrangle as the area is called, being bounded by parallels and meridians, respectively thirty minutes of arc of the earth's surface apart. In this latitude a topographic sheet or quadrangle is about twenty-four and one-half by thirty-four and one half miles in extent and embraces an area of a little less than 850 square miles.

On the topographic map or sheet the elevation of every part of the area is shown, also all the lakes and rivers and smaller streams, towns, railroads, public highways and houses. The maps are printed on a scale of one-half inch to the mile. This makes each section of land appear on a scale suitable for further detailed studies.

Ten topographic sheets have thus far been made in North Dakota, which are designated as follows, the name being derived from the principal town centrally located on the quadrangle: Fargo, Casselton, Tower, Eckelson, Jamestown, Pingree, Wahpeton, LaMoure, Edgeley and Wyndmere (the last named having been surveyed in 1904.)

Biological Survey.—Owing to the limited state of the survey finances it was deemed best not to attempt any further study of the native grasses and forage plants until funds should be available sufficient to carry on the work adequately and fully enough to make it possible to reach some definite conclusions.

Chemical Survey.—Arrangements were planned to have a chemical survey made of the region about Devils Lake, and the lakes in the adjacent portions of the state, but the funds were found to be insufficient to carry the work to adequate completion, and the effort was abandoned for the present season.

The purpose of this survey was to determine from analysis of soil samples taken from the different soil types in the region, and from analysis of water from Devils Lake and the lakes and streams of the neighborhood, what is the relative percentage of salts and alkalies in the soils and waters of the region as compared with the waters of Devils Lake. This would give a basis for determining the cause of the saltness of Devils Lake, and also a key to the best treatment of lands in which salts and alkalies are found.

The Personnel of the Survey.—The state has been fortunate in securing the services of young men of so high a degree of special fitness and training for the various lines of investigation represented. It has been, and will continue to be the aim of the Survey, to interest young men from our own state in the work of the Survey. It is hoped that trained men may ultimately be secured from our own state who will be able to conduct the highest class of investigation. Several young men from the Agricultural College and other institutions have been engaged upon the different lines represented by the survey. It is hoped that of this number at least some will find a congenial atmosphere in the domain of geology, and will become professional workers in this field. Such men are in demand both by the state and the United States, and it seems fair to presume that there will continue to be an increasing demand for such trained experts as the development of the resources of the state continues and the importance and value of accurate scientific investigations becomes more fully realized.

The state has been particularly fortunate in securing the services of Mr. H. V. Hibbard, as assistant in the department of areal geology and underground waters. Mr. Hibbard was for several years a student in the department of geology of the University of Chicago, and now professor of geography in the Hyde Park high school, Chicago. His preparation for the accurate work of the department he has represented has been of the highest order, having had the benefit of training under the direct instruction of the foremost geologists in America. His experience in practical field methods therefore renders his services of the greatest value. By reason of Mr. Hibbard's assistance it has been possible to extend the work in this department beyond what would otherwise have been possible.

Cost.—The amount appropriated by the last legislative assembly for the maintenance of the Agricultural College Survey was $2,-000. As the Survey was organized to co-operate with the federal surveys, the amount made available by the state would naturally determine the amount of co-operation into which the federal surveys would enter, and the amount also which the state desired. However, the federal authorities have taken good will at its full value, and have expended a much larger amount than the state appropriated in the hope that more active co-operation on the part of the state would be provided for when the next legislative assembly should convene. The aggregate expended by the federal surveys in co-operation with the Agricultural College Survey in the divisions of soil, areal geology and underground waters, and topography is upwards of $10,000 for the years 1903-4, aside from the cost of the publication of reports.

It can hardly be hoped that the federal authorities will continue to expend funds so generously in our state unless some active appreciation of the generosity manifested be shown by reasonably adequate provision of funds by the state.

Needs of the Survey.—So urgent is the demand for adequate funds and so great the value of the work to the state which has been begun and thus far carried on principally at the expense of the federal government that I desire most respectfully to call your attention to the needs of the several divisions represented by the Agricultural College Survey. The topographic survey forms the basis for all further detailed surveys. The cost of making a topographic map averages about $3,000. The policy of the government is to expend in each state an amount equal to that provided by the state itself. In order to have the topographic survey progress with rapidity and in accord with the general progress of the work in other lines, one sheet at least should be prepared each year. Thus the state in order to meet the generosity of the federal government should provide $1,500 per year for this work.

Similarly, the work of the soil survey has been heretofore done almost entirely by the federal department, but in the hope that the state would realize the benefit and value of the work and provide an annual sum sufficient to meet that offered by the federal government. For this work the federal government has expended during the past two years about $3,000, or $1,500 per year.

The division of hydrography of the United States Geological Survey has expended about the same amount annually.

In addition to the lines of co-operative work above mentioned the Agricultural College Survey has, in conformity with the purpose expressed in the law organizing the survey, undertaken to complete an economic and geologic map of the state. As a part of this work the survey has undertaken the preparation of a map showing the different characters of lands, the soils and waters, also the native grasses and forage plants, in the western portion of the state—a portion of the state, as has been stated before, that has never been accurately mapped—looking toward a more complete geologic and economic map of the state. For this work $1,000 per year is needed.

I would also most respectfully urge the necessity of provision of sufficient funds to maintain the chemical and biological divisions of the survey, and also to provide for permanently preserving specimens of soils, rocks, minerals and other material, such as is being collected each year, but for the preservation of which no adequate provision has been made.

The investigations which are contemplated in the division of chemistry include both field studies and laboratory analyses. Five hundred dollars per year for the biennial period will be needed to carry to satisfactory completion the field and laboratory investigations which it is hoped to undertake, $300 being the estimated necessary cost of the field work, and $200 that for laboratory materials, and the services of competent assistants.

For the biological survey and the preservation of material collected in the work, $500 per year ought to be expended in order to yield the best results.

In the interest of the fullest conservation of the results of the survey, I would recommend that suitable cases for the preservation and storage of the valuable material which is each year collected by the different field parties be made. One hundred dollars per year would make it possible to preserve each year material representing a value for educational purposes and the work of allied departments of the college almost beyond expression in figures.

Summarizing the above figures, I desire to recommend the appropriation of the following amounts, to be used in the discretion of the director for the following purposes:

OBJECT FOR WHICH USED	ANNUALLY
For topographic survey	$ 1,500
For soil surveys	1,000
For survey coteaus of the Missouri ..	1,000
For division of chemical investigations	500
For biological survey	500
For preservation of material	100
For director's expenses and incidentals	400
Total for all purposes	$ 5,000

Charles Monroe Hall.

ACCOMPANYING PAPERS.

THE LIFE AND WORK OF PROFESSOR CHARLES M. HALL.

BY WARREN UPHAM, ST. PAUL, MINN.

From the American Geologist, April, 1902.

In the comparatively new states west of Minnesota, resident geologists are few. Many problems of theoretic and economic geology wait there to be worked out. The death of a young geologist, who was well equipped and earnest for this work, who had grown from boyhood to manhood in North Dakota, whom to know was to esteem and love, is therefore a great loss, not only to his personal friends, but to the wider interests of education and science.

Charles Monroe Hall was born in Wellington, Ohio, October 21, 1870. When he was about twelve years old, his parents and the family removed to North Dakota (then a part of Dakota Territory), settling in Stutsman county, near the present town of Eldridge. Later they removed to Grand Rapids, on the James river in LaMoure county, where they engaged several years in farming. In 1891 his parents removed to the state of Virginia, where they have since resided. Charles, however, preferred to remain in North Dakota, entered the State Agricultural College at Fargo, went through the usual course of four years, and was graduated in 1895, with high honors.

Immediately after his graduation, he was appointed assistant professor of chemistry and geology in that college, where he taught during the next two years. To better qualify himself for his duties there, he then obtained a leave of absence for a year of special studies in Johns Hopkins University.

Frederick Bennett Wright, his room-mate during this year at Baltimore, writes: "In the autumn of 1897 Mr. Hall entered the graduate department of geology. His enthusiasm in the work,

together with his attractive personal characteristics, soon won for him a genuine popularity within the circle of geological professors and students among whom he had come. Although his interest in the work before him was general, he was more attracted by structural and physiographic subjects than by those of mineralogy and paleontology. His life at Fargo, in the old bed of lake Agassiz, naturally gave him a keen interest also in glacial geology. During his stay at Johns Hopkins, he worked for a short time on the Maryland Geological Survey, along the Potomac river. There his work was so thorough and satisfactory that he was offered a position in that state survey, for field work on the coastal plain the following summer. But his teaching and plans for field work in North Dakota were more attractive and caused him to return there. Personally he was very modest about his accomplishments, but yet had a sufficient sense of their importance to give him the confidence in himself necessary for success. I was greatly impressed with his broad views on all subjects, and his wide interest in general topics. We often had heated discussions, though perfectly friendly, which sometimes lasted till after midnight, on all conceivable subjects, from geology, evolution, and theology, to music and art."

Returning in the summer of 1898 to the Agricultural College of North Dakota, and being promoted to its professorship of geology, Hall was constantly engaged, through the remaining four and a half years of his life, in his duties as a college instructor, including frequent excursions with his classes, and in more extensive examinations of distant parts of the state during vacations.

In the summer of 1900 he began a systematic investigation of the artesian wells and underground water resources of North Dakota, through cooperation by the Agricultural College with the United States Geological Survey. Previously also he had aided Professor J. E. Todd, during one or two summers, on similar work in a part of the James river valley in South Dakota.

Besides the hydrographic work, he began at the same time a survey of the soils of North Dakota, being associated with F. H. Newell and Milton Whitney of the U. S. Geological Survey, in their respective departments of hydrology and soil investigations. Manuscript reports and maps, notes of stream measurements, records of artesian wells, collections and analyses of soils, etc.,

relating to parts of these researches already completed or well advanced, had been forwarded to Washington, but they still await publication.

Professor Hall had presented some of the results of this work in a series of newspaper articles, concerning the water supply of Fargo, the artesian basin and wells of the Red river valley and westward, irrigation for the drier western parts of the state, and the capabilities of its different regions for agriculture and grazing, these articles being published in the Fargo *Forum and Daily Republican*, the Wahpeton *Gazette*, the Minneapolis *Journal*, and other newspapers, during the years 1900 to 1902.

One of the most important of these contributions is entitled "A Discussion of the Water Resources of Fargo and Vicinity, with Special Consideration of Possible Sources of Water for a Better Supply for the City," which filled four columns of the *Forum*, June 24, 1902. It is accompanied with a section across Red river valley, on the line of the Northern Pacific railway, and a map which shows the limit of the chief artesian basin, receiving water from the Dakota sandstone, and the smaller areas of the valley receiving usually scantier flows from the drift deposits.

Within the last month before his death, he completed a manuscript for the supplement in a school geography to be published by the American Book Company, this supplement being a "Geography of North Dakota."

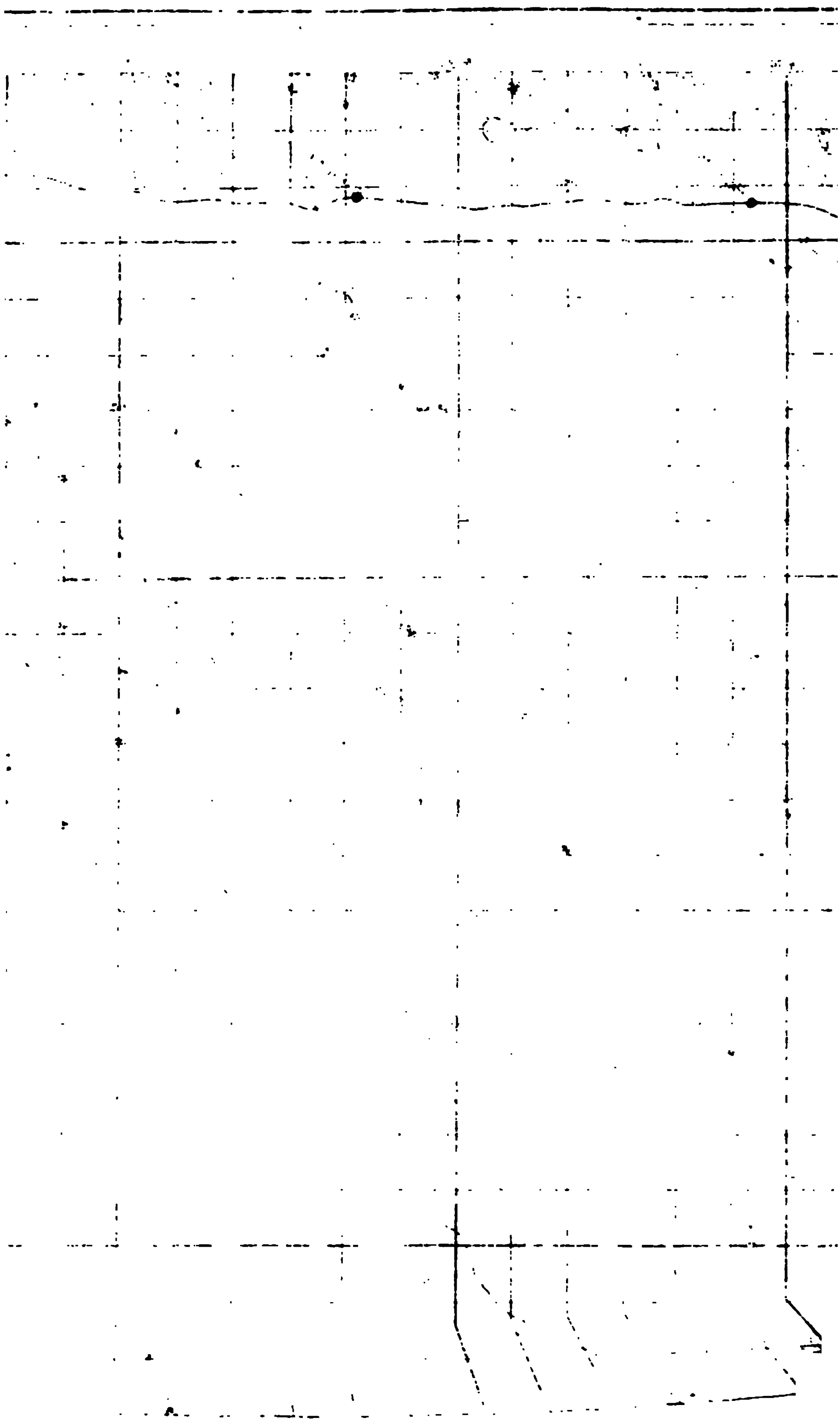
Professor Hall represented his state through appointment by the governor, in the Tenth National Irrigation Congress, held at Colorado Springs, October 6 to 9 of last year; and in the Fargo *Forum* of November 22 he published a considerable report of its proceedings, with earnest recommendation that North Dakota should take a larger share, in connection with the U. S. geological and hydrographical surveys, for the development of irrigation.

The latest and perhaps the most important work which Professor Hall brought to completion and publication, as printed in December, 1902, is an "Official State Map and Preliminary Geologic and Economic Map of North Dakota, issued by the Agricultural College Survey * * * in cooperation with the U. S. Geological Survey; approved by Frank White, governor of North Dakota, and R. J. Turner, commissioner of agriculture and labor." The scale of this map is seventeen miles to an inch. The western half of the state,

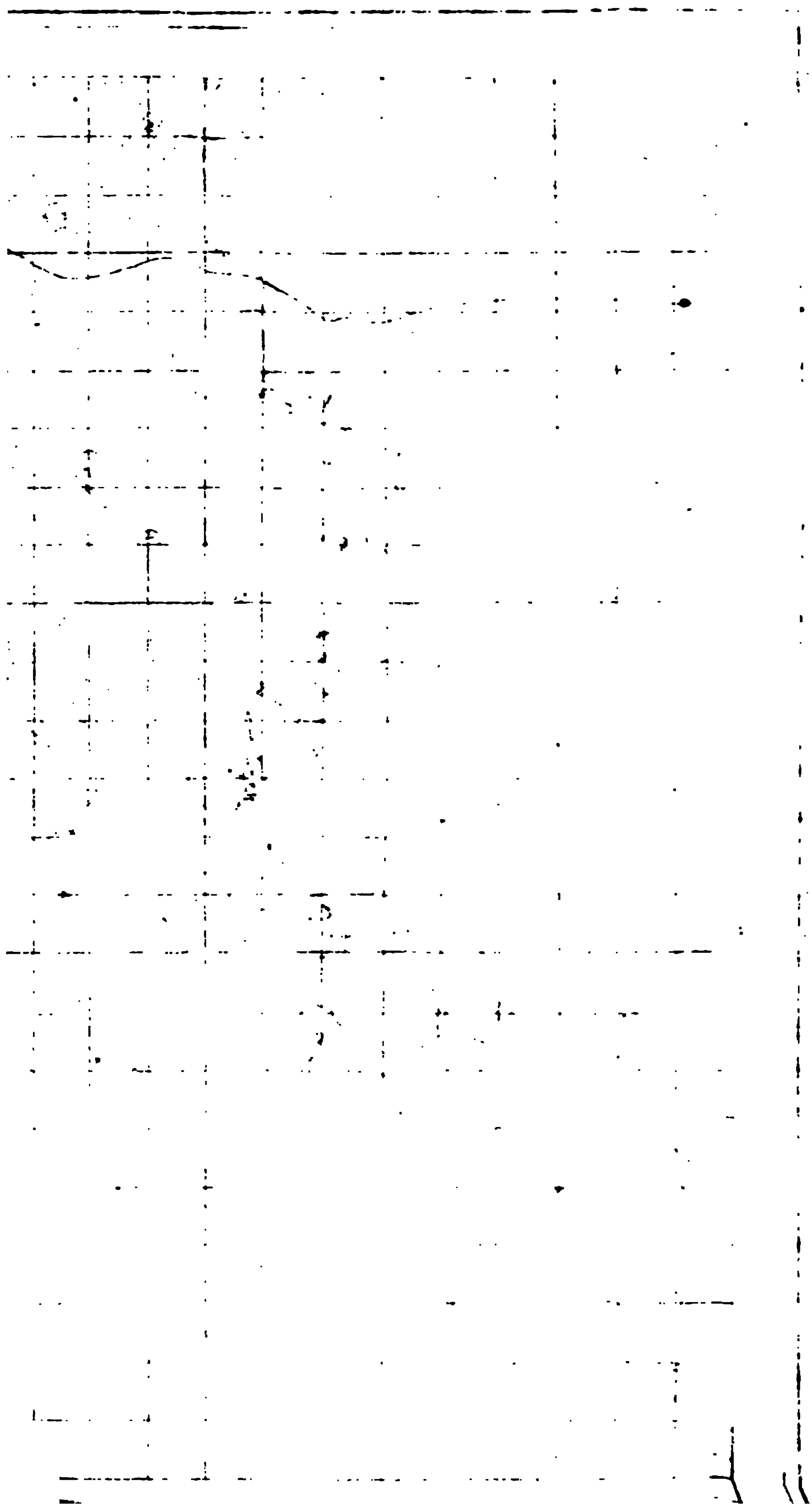
and the Turtle mountains, are colored as Laramie clays and shales, with many outcrops and mines or openings of workable lignite. Thence eastward the remainder of the state, excepting the area of the glacial lake Agassiz, is colored as glacial drift overlying the Montana shales of Upper Cretaceous age. Upon these colors the courses of the marginal moraine belts are shown by another color printing. On the eastern border is the part of lake Agassiz west of the Red river, with its large Sheyenne, Elk Valley, and Pembina deltas. The extreme limit of the glacial drift, and the boundaries of the Dakota artesian basin, are designated approximately.

October 22, 1901, Professor Hall was married to Miss Jessie E. Taylor, of Fargo, and their life together was one of remarkable happiness and mutual helpfulness. They both were members of the First Methodist Episcopal church of Fargo, and of its choir. Professor Hall was also a member of the Masonic fraternity, the Knights Templar, and other social organizations.

His last illness was diagnosed by physicians, half a year before he died, as probably to prove fatal within a year, or, at the longest, a few years. Yet he courageously continued his teaching and his plans for the state agricultural survey. One of his last pieces of work was to frame a legislative act giving to that survey, as aided by that of the United States, a distinct field not duplicating the work of the State Geological Survey, which is in progress under the auspices of the State University and School of Mines of North Dakota, at Grand Forks. His work of instruction in the college was continued until only three days before his death, which occurred at his home in Fargo the 22d of January, 1903. For him is the divine promsie, "Be thou faithful unto death, and I will give thee a crown of life."



NORTH DAKOTA GEOLOGICAL SURVEY



A SURVEY OF THE COTEAUS OF THE MISSOURI.

By Daniel E. Willard and M. B. Erickson.

What the Coteaus Are.—A great region lying east of the Missouri river was called by the early French explorers "Les Coteaux du Plateau du Missouri," or The Hills of the Missouri Plateau. In the popular mind the hills or "coteaus" and the plateau are confused, the term "coteaus" being often applied to the great hilly upland which is the plateau, and a surface feature of which is the "coteaus" or hills. We shall therefore attempt to make clear the relation of the "coteaus" to the plateau.

"Les Coteaux du Plateau du Missouri" may be briefly and for convenience styled the coteaus of the Missouri, or the Missouri coteaus. Les Coteaux des Prairies, from which the former should be carefully distinguished, is another and quite distinct feature of the landscape of the states of North and South Dakota. The latter is an immense hill many times larger than any one of the Missouri coteaus, lying mostly in northeastern South Dakota but extending across the border into North Dakota near Havana and Lidgerwood. Le Coteau des Prairies is a large preglacial hill having its surface covered with a mantle of drift hills much like the coteaus of the Missouri only not generally as large. The coteaus of the Missouri are morainic hills.

Le Plateau du Missouri, or the Missouri Plateau, is a vast upland of preglacial origin. The eastern edge of this upland extends across North Dakota in a generally northwest and southeast direction. The front rises quite abruptly from the plain to the east from 300 to 400 feet. This steep slope or front appears west of Ellendale, Edgeley, Jamestown, Carrington, Fessenden, Minot and Portal, distant from these places twenty to thirty miles.

This plateau it has been stated is a preglacial landscape feature. It was not in any manner formed by the ice of the glacial period.

Lying on the top of the plateau is a great belt or tract of hills, drift hills formed by the action of the great ice sheet during the glacial period, which together make up what is known as a moraine.

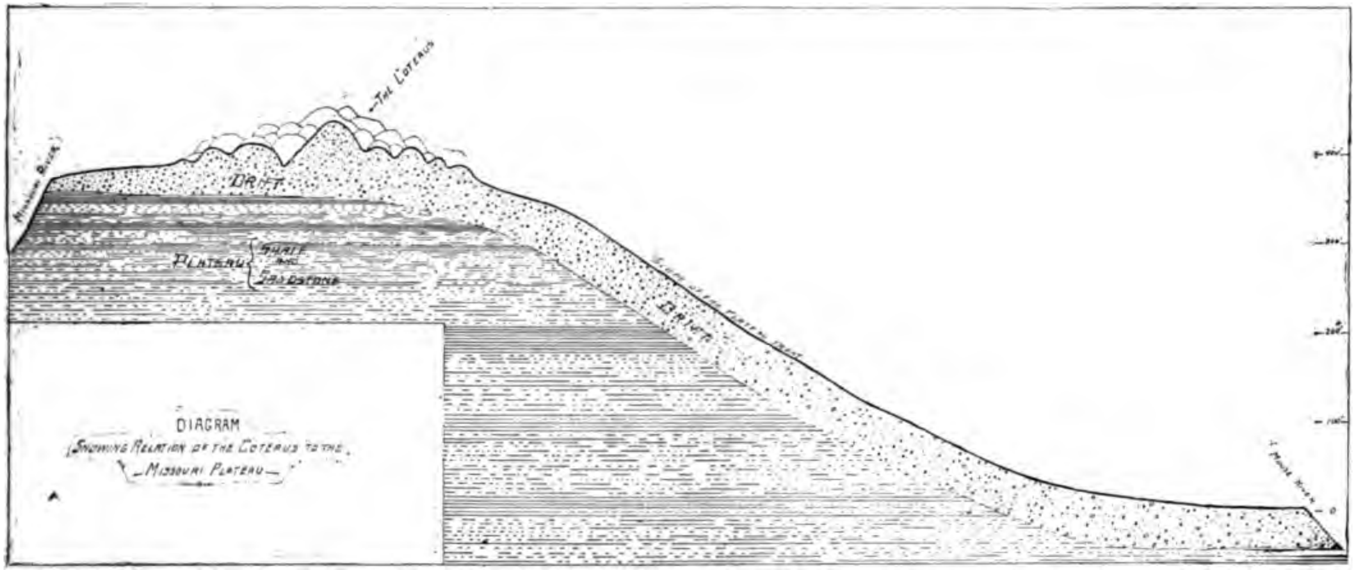
This moraine in North Dakota is a portion of the great continental moraine which was formed during what is known as the Wisconsin stage of the great ice age. This moraine extends across the continent from the Canadian northwest territories to the Atlantic ocean. The moraine in North Dakota is no more a part of the great Missouri plateau than is this same moraine in Pennsylvania a part of the Allegheny mountains. The moraine is a deposit of earth materials—stones, clay, sand, and soil—ploughed up and transported by the great moving ice sheet, and left in heaps and piles or spread out as rolling prairie, to a depth of thirty to 100 or even 150 feet.

The continental moraine in North Dakota lies in such relation to the plateau that it suggests that something more than accident caused the moraine to lie just upon the edge of the plateau through a distance of 300 miles in North Dakota. The front or edge of the plateau, it has been stated before, extends across the state in a northwest-southeast direction. The moraine also extends across the state lying almost parallel to the edge of the plateau, and nowhere more than a few miles back from the slope which marks the edge of the plateau. Often in fact the coteaus or hills of the moraine are encountered immediately upon entering upon the higher lands of the plateau top. The accompanying diagram (Plate IV) will assist in making clear the relations.

The direction of movement of the ice of the great ice sheet in this part of North America was probably very nearly at right angles to the front of the great plateau, so that the escarpment of the plateau served as a dam to hold back the ice in its onward movement, and so the moraine occurs along the edge of the plateau because the ice could not advance beyond this position, a moraine always being formed at the edge of the ice sheet.

It is because of the occurrence of the moraine upon the edge of the plateau that so much confusion has arisen regarding the true nature of the coteaus. The term "coteaus" has been applied to the hills in this region. The altitude of the plateau above the prairie to the eastward has easily made this seem a part of "the hills," whereas the coteaus are hills on the top of the plateau and entirely different in their origin.

The Purpose of the Survey.—The extent of territory embraced by this great moraine within the state of North Dakota is probably



Idealized Cross-section of Missouri Plateau Southwest from Minot.

A Stony Ridge.

A Small Lake in Morainic District.

approximately 7,000 square miles. This region has until the last two or three years been mostly an undisturbed grazing range, native grasses adapted during the ages to the soil conditions of such a landscape growing in abundance, and eaten by the herds of cattle and horses which during the last thirty to forty years have succeeded the herds of buffalo and antelope that formerly roamed and grazed on these lands. The agricultural value of the lands was an unknown factor. The ranchman was the only settler. Little was known of the character of the lands, and little question was asked by homeseekers about these lands because there were other more desirable lands open to homestead entry.

Within the last two or three years, however, the demand for homestead lands has led to the settlement of some portions of these lands by farmers. The need for a scientific survey of the region and some determination of the character of the lands and their adaptability to farming or stock raising has therefore been more keenly felt. The region has long been regarded as adapted only to grazing, and no attempt at general farming has been made until very recently. The settlement of a farmer upon an occasional quarter section effectually overthrows the large ranching enterprises where cattle in great herds wander at will over a range unbounded by fences and limited only by the instinct of animals to stay about some central locality.

From a scientific standpoint a survey of the region was needed. The great continental moraine has been definitely mapped in all its vast extent from the Missouri river eastward to the Atlantic ocean, that portion only which lies north of the main line of the Northern Pacific railroad in North Dakota and thence on to the northwestern corner of the state remaining unmapped.

An Unique Part of North Dakota.—The region known as "the coteaus" is unlike any other part of North Dakota. There are other morainic lands in the state, but none that can vie with this region in rugged character, in abundance of the number of sloughs and lakes, and in the "everlasting monotony." It is not like the rugged hill-land west of the Missouri river, for there the hills nearly all have flat tops, and the land is nearly all cut up by streams and dissected by deep coulees. Streams are unknown among the coteaus, and the hills are all rounded in form and never flat on their tops.

This region is one that marks the halting-place of the great continental ice sheet in its passage across the northern portion of North America, and here was deposited the great mass of morainic material—rocks, sand, gravel, clay and soil; huge boulders so hard that they would phase the hardest stone-cutter's chisel and weighing many tons side by side with small rounded pebbles and sand grains, masses of clay and soil piled in heaps, hollows filled with water or grown up with reeds and rushes.

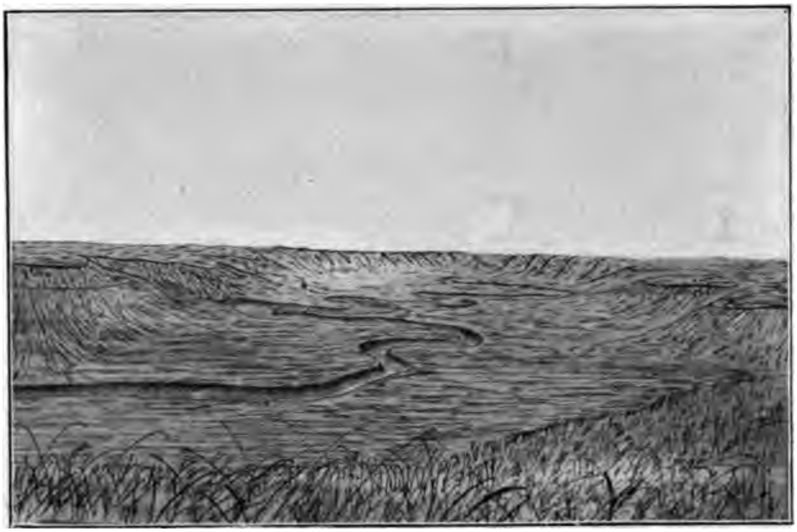
It is truly the region of hills—coteaus. They are the coteaus of the Missouri plateau because they are on the plateau. They are the highest and most rugged of morainic hills in the state because they were formed at the edge of the great ice sheet at a stage when the edge remained stationary, neither advancing nor melting back, for a longer time than at any other stage.

The Area Surveyed.—The portion of the great moraine lying south of the Northern Pacific railroad within the state of North Dakota has been mapped by Mr. J. E. Todd, of the South Dakota Geological Survey and the U. S. Geological Survey. The unmapped portion therefore extends from the Northern Pacific railroad between Steele and Bismarck north to the extreme northwest corner of the state.

Minot was made the railroad point of entrance to the field, and the first camp was established on section 22, township 152 north, range 84 west. From this point a careful study of the adjacent region was made, the plan being to extend the work both northwest and southeast till the limits of the state should be reached on the one hand and the area already surveyed and mapped by Todd on the other. The eastern side of range 83 was made the eastern limit of the area studied during the season of 1903, and during 1904 the work was extended over the territory westward to range 92, the territory included in the Fort Berthold Indian reservation not being included. The area mapped thus includes two tiers of townships in McLean county and extends to and includes the tier of townships crossed by the Great Northern railroad in Ward county.

DESCRIPTION OF THE AREA.

Three Types of Landscape.—The accompanying map shows fifty-eight townships. The area includes three types of landscape, viz., (a) a region which was passed over by the ice but which is not covered by moraines; (b) a region of strong morainic hills, lakes



Douglas Valley, South of Douglas Postoffice.

One of the Largest Hills in the Region.

and sloughs—the coteaus, and (c) a region outside the great moraine, west of the coteaus, a region over which the waters from the melting ice of the great glacier passed forming many broad and deep channels, and which may be called the region of overwash.

The first of these types of landscape is represented on the northeast portion of the map. This region is not included in the "hill country" of the coteaus, and is not a part of the region intended to be studied in this survey. It is shown on the map for purposes of comparison. This is rolling prairie, technically called ground moraine, and is adapted to general agricultural purposes. The line delimiting the ground moraine or rolling prairie from the morainic hilly land, the coteaus, crosses in a northwest-southeasterly direction the following townships: Township 152, range 83; township 153, ranges 83-84; township 154, ranges 84-85; township 155, ranges 85-86, and township 156, range 87.

This region is dissected by coulees. It has no lakes or sloughs of much importance. The coulees are deep, due to the fall or slope from the high plateau region toward the Mouse and Des Lacs valleys.

The second or morainic type of landscape, the real coteaus, includes the body of the area mapped. Here will be observed an utter absence of streams or coulees and many lakes and sloughs. The hilly portions of the map are indicated by the dotted shading.

The third type is that of the overwash region, represented on that portion of the map not shaded and marked by deep and broad valleys. This type is represented on the southwestern portion of the area mapped. It is a region over which the ice did not pass during the stage known as the Wisconsin, or the stage when the morainic hills known as the coteaus were formed, but over which passed vast floods of water, overwash from the melting of the great icesheet, and which has been eroded so that large channels have been formed, and extensive deposits of gravel have been left.

The Older and the Newer Drift.—In order to avoid possible confusion in the mind of the reader, who may question how the moraine, called the coteaus, can represent the edge of the ice sheet when drift materials are known to occur over a territory extending fifty miles west of the Missouri river, a word needs to be said regarding

the earlier and the later stages of the ice sheet in this portion of North America.

It may be assumed that the reader is familiar with the elementary facts of glacial geology, as the discussion of these facts here would involve more space than can be devoted to it.* However a brief statement of the facts regarding the older and the newer drift will be given here.

The moraine which is the principal subject of this paper, and which embraces the greater portion of the territory described in this survey, was formed at the edge of the ice during what is known as the Wisconsin stage of the great ice sheet. This moraine thus marks the limit of advance of the ice sheet during this epoch or stage of the glacial period.

It will thus be seen that the drift which lies west of the Missouri river does not belong to this stage or time; it is much older. An earlier invasion of ice from the north, the stage known as the Albertan, passed over this portion of North America long before the later invasion which formed the coteaus. A mantle of drift therefore covers the territory lying outside or west of the moraine formed during the Wisconsin stage and known as the coteaus. This drift in some places has been nearly all washed away so that but little or none at all remains covering the original land surface. It is often deeply eroded by the streams of ice water which flowed away from the great glacier of the Wisconsin stage. The valleys of Douglas creek, Shell creek and Little Knife river are examples of such channels that have been eroded into the older drift in their upper courses, and farther toward the Missouri river have cut entirely through the mantle of older drift into the underlying rock, as is shown by the outcropping ledges of sandstone, shale and lignite coal along the banks of these streams.

Further Description of the Area — The Eastern Slope.—The deep valleys of the Des Lacs and Mouse rivers cross the northeastern portion of the area included in the map. These valleys are broad and deep beyond all comparison with valleys made by rivers of such sizes as those now occupying these valleys. They are glacial

*To the reader who may be interested such a simple statement of the general geology of the state as is needful to an understanding of the present report, it may be suggested that a little book, "The Story of the Prairies," is a simple and popular description of the geology of North Dakota, and to this work the reader is respectfully referred. The book is published and for sale by the author, Daniel E. Willard, Fargo, N. D.

valleys, channels cut by the flood waters from the melting ice sheet. They have been eroded 300 feet into the plain which lies east of the great Missouri plateau. That their bottoms are below the lowest portions of the mantle of drift is shown by the occurence of sandstone ledges and lignite coal beds in their banks.

The plain which is crossed by these valleys is the characteristic rolling prairie of a large part of North Dakota. It is the rolling prairie for which the state is noted, and which makes North Dakota a "prairie state." This particular parcel of rolling prairie is a segment of the sloping front or edge of the great Missouri plateau. While the plain along the banks of the deep valleys of the Mouse and Des Lacs rivers is 300 feet above the bottom lands along the immediate stream beds, still the plateau top thirty miles west is more than 300 feet higher than this plain.

It is this slope from the edge of the plateau toward the deep valleys that gives the dissected character to the landscape. A rise of nearly 700 feet in a distance of forty miles in the railroad grade of the Great Northern railway from Minot westward has made possible the erosion of the deep and narrow V-shaped coulees which characterize the region.

Description of the Moraine.—The hilly region of the moraine in the area under consideration is from fifteen to twenty-five miles in width. This tract is made up of hills, ridges, rolling or even gently undulating prairie lakes, sloughs and hay meadows. A moraine is thus seen to be a somewhat complex thing.

The general aspect of the landscape after entering the morainic region is distinctly hilly. Many of the hills are high and their sides very steep and rugged. Often they are so closely set together that there is no space between the bases of the hills, but the bottom of one merges into its nearest neighbors. Occasionally a hill is so decked with stones large and small that the face of the hill appears like a vast stone heap.

Travel through the hills to one unaccustomed to the region is almost impossible, not only because of the roughness of the landscape and the frequent large rocks, but the hills all have such a resemblance that the inexperienced traveler easily mistakes the hill he thinks he is traveling toward, another insidiously substituting itself for the one he started to reach, while the traveler uncon-

sciously changes his course to go around a hill or avoid a slough. Where definite trails do not serve as a guide to the traveler he is almost helpless, and a journey is well nigh impossible.

The hills are sometimes so stony and steep that progress on horseback by one who is not accustomed to "the range" is almost impossible, a horse being liable to fall owing to the great number of rounded stones and the exceeding steepness of the slopes. Following a well worn trail one can often see his way but a few rods or even a few feet ahead, so crooked is the way as it winds and swings this way and that, among the hills. Leave the beaten past but a few steps and the unaccustomed traveler is as one adrift on the rolling sea.

One may be lost and pass within a few rods of a rachman's shack and not see it, for the shack may be and often is located in a hollow between the hills so that it cannot be seen often even from a short distance. The writer speaks from experience in seeking to find a ranch house while traveling a stranger and alone in this solitary region. A miss of a single dim fork in the trail caused him to pass by the last house in many miles, and as a result he lay down fatigued to the point of exhaustion upon the hard bosom of Mother Earth, and slept with the picket rope by which his saddle pony was held tied around his body till the cold of the small hours of the morning compelled him to travel on eagerly looking for the dawn which should enable him to find food—and what was more intensely needed, water.

A common custom is to place upon the highest points of the highest hills piles of rocks with often a pole supported in the midst of the rocks as a guide to the traveler. Such a landmark is always known to the inhabitants of the country, and if lost in fog or storm and one of these marks is seen it will indicate quite as accurately as section corners in the agricultural portions of the state where a ranch house is located.

One may pass a herd of hundreds of cattle within a few rods or even go through the herd where the animals are grazing in the hollows or on the slopes and perhaps be unaware of the herd's presence.

Tracts Less Hilly.—The whole of the morainic region is not of the extremely hilly type. Inter-morainic tracts embracing from a few acres to a hundred acres or sometimes more occur, and these

Looking Along a Stony Ridge.

Eroded Hill and Glacial Drainage Channel, Douglas Valley.

Looking Along a Stony Ridge.

Eroded Hill and Glacial Drainage Channel, Douglas Valley.

quantities is cut in them and stacked for winter feeding. If this great coteau region could be used exclusively for grazing without interference from attempted farming on the few small areas on which farming is at all practicable, and could be used to its full capacity, a vast source of wealth to the state would result. This is not saying that the present wholesale range and wasteful methods in vogue on the ranches would accomplish this end, but if the low and more level tracts such as are capable of profitable plowing could be used by stockraising farmers for the growth of alfalfa, corn and other coarse forage crops for winter feeding, and all the hay which grows in the sloughs could be untilized, so that enough herds could be wintered to eat all the grass which grows on the inaccessible hillsides and rough lands, a livestock interest vastly greater than that which the region has heretofore sustained would be possible.

The Extra-Morainic Territory.—There remains to be described the territory lying west of the morainic tract between this tract and the Missouri river. This has been referred to as the overwash region adjoining the moraine.

It has been pointed out before that the region is mantled with the older Albertan drift, and that it has been furrowed and eroded into deep channels by the pasage of the waters of the melting ice sheet southward and westward into the Missouri river.

It will be seen by reference to the map (Plate III) that the eastern edge of the moraine is quite definite and simple, whereas the western side is very irregular, the moraine being indented by deep sinuses and inverted loops. This is the usual thing that the outside of a moraine is ragged and uneven while the inside or that toward the ice sheet is comparatively even. This will be readily understood when it is borne in mind that the great moving ice mass pressed upon the east and north side of the moraine while at the same time the materials of which the hills of the moraine are composed were being deposited by the ice and the edge of the melting ice sheet was jagged and uneven, due to unequal melting. Long lobes pushed out from the front of the ice also, and thus the outer edge of the great deposit from the ice, which is known as a moraine, is very irregular and uneven.

One of the most conspicuous of these embayments in the moraine with its corresponding lobe of hills has been called the Douglas valley, from the name of the small creek that now occupies the old

are sometimes fertile and adapted to cultivation. These intermorainic tracts are not, however, generally extensive enough or frequent enough to lend much importance to the region for general agricultural purposes. The hills are too stony and the soil too compact, dry and hard to render farming generally profitable or practicable.

All the region represented on the map by the shaded portion falls in the class of morainic lands and is not regarded as advantageous farming land. This does not mean that there are not some quarter sections that are desirable, and there are a few sections that might be untilized as farming lands. In time, as land becomes more valuable in agricultural districts, these lands which are now one great public domain will fall into private ownership, and the less hilly portions will probably be cultivated and the more hilly parts used for pasturage.

The region is a natural pasture land. The native grasses are very nutritious, and cattle and horses thrive during the whole year upon the forage, which cures as it stands, with only a little feeding in the winter. At present, and it seems likely for many years to come, that portion of this district which is included in the morainic tract will be more valuable for grazing and stockraising than for general farming. The settling of a few farmers in the hill country works serious injury to the stockraising industry, and really detracts from the development of the wealth of the state rather than adding to it, since the plowing and raising of cereal crops on a few small patches prevents the free range of stock over the hill country surrounding, and thus causes a vastly greater area to lie desert.

A further feature that adds to the value of these lands for exclusively grazing purposes is the great number of "dry" lakes or sloughs, which are often real lakes during the season of heavy rains or melting snows, the hay meadows. These small lakes and sloughs are a characteristic feature of the morainic territory. There are sometimes so many of these that travel during the season when they contain water or when they are too wet to be crossed is almost impossible. There are sometimes as many as fifty to 100 of these small hay meadows, lakes or sloughs, on a single section, though perhaps twenty-five to forty on a section would be about an average.

These furnish forage during seasons when the hillsides do not produce enough grass for the herds, and hay in almost unlimited

quantities is cut in them and stacked for winter feeding. If this great coteau region could be used exclusively for grazing without interference from attempted farming on the few small areas on which farming is at all practicable, and could be used to its full capacity, a vast source of wealth to the state would result. This is not saying that the present wholesale range and wasteful methods in vogue on the ranches would accomplish this end, but if the low and more level tracts such as are capable of profitable plowing could be used by stockraising farmers for the growth of alfalfa, corn and other coarse forage crops for winter feeding, and all the hay which grows in the sloughs could be untilized, so that enough herds could be wintered to eat all the grass which grows on the inaccessible hillsides and rough lands, a livestock interest vastly greater than that which the region has heretofore sustained would be possible.

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One of the most conspicuous of these embayments in the moraine with its corresponding lobe of hills has been called the Douglas valley, from the name of the small creek that now occupies the old

A Landmark.

The Home of an Early Settler.

Road Ditch Eroded in Four Years. Ditch Discharging Into Red River of the North.
Township 140, Range 48.

channel below Douglas postoffice. This "valley" includes portions of townships 149-152, ranges 84-85.

The upper portion of this valley is beautifully set with lakes, in fact the Rice lake and Bartron's lake are among the most beautiful and clear in the state, having fine gravelly shores and bottoms. The surface is far from level in the portion of this valley above Douglas; on the other hand it is quite distinctly rolling or even hilly, and the soil is compact and stony, much like that of the moraine over much of it. The valley is not a valley at all as that term is ordinarily used. It is rather an overwash plain from the great ice sheet. The tract of gravelly and sandy soil in the northern portion of the valley is probably thus explained.

South from Bartron's lake and Douglas postoffice the valley-like character becomes more conspicuous. The surface is more nearly level, and the soil is sandy and gravelly, assorted and washed by the glacial flood waters.

Extensive plains of gravelly and sandy soil lie along the border of the moraine, typical examples of overwash from the ice sheet. Frequently such plains can be distinguished from a distance by observing the characteristic growth of weeds and grasses which thrive upon such soil.

A BRIEF HISTORY OF GLACIAL LAKE AGASSIZ.

A POSTHUMOUS PAPER BY CHARLES M. HALL.

TOPOGRAPHY.

The area considered in this paper lies within the region known as the Red River valley, which, during the closing stages of the glacial period was filed with water and known as Glacial Lake Agassiz. This region has been described by Mr. Warren Upham in U. S. Geological Survey Monograph XXV.

The topography is exceedingly simple. Two-thirds of this area lies as one vast level plain. Standing near the middle of the valley, if we may call it a valley, one looks across this vast expanse as far as the eye can reach, with his vision interrupted only by the groves planted by the early settlers, and marking the location of these older farm buildings, and the trees which border the winding courses of the streams. One is reminded of the level of the mighty

ocean, indeed in many places one's vision is bounded apparently in all directions by the tops of buildings and trees in the far distance like the masts of a ship disappearing at sea, no physiographic feature being great enough to be detected by the eye from the level. This feature is explained in the U. S. G. S. Topographic Atlas entitled "Physiographic Types," where the Fargo quadrangle is used to represent a region in youth. The general altitude of the level plain is about 900 feet above sea level. On either side of the Red River of the North which flows from south to north across the area the land rises with a gentle slope of from 1 to 4 feet per mile. Approaching the western bottom of the old lake bottom the surface is marked by a more sudden rise and broken by a series of ridges running north and south which mark the beaches of the old lake at its different stages. In the northern part of the area there is a rise of 200 feet in a distance of about 5 miles to the upper or highest level of the old lake. Beyond this the rolling prairie merges into the low morainic hills just west of this distrct, the highest part of the area now being considered being crossed in the northwest corner by the 1,200 foot contour.

In the southern half of the area, or south from the point where the Maple River debouches upon the old lake bottom, the margin of the lake bottom is marked by a more sudden rise of about 60 or 70 feet within two or three miles onto a sand plain almost as nearly level as the lake bottom itself. This plain extends from a little north of the Maple River beyond the limits of the area to the south. It is broken by the Maple and Sheyenne valleys. The Sheyenne River has eroded a gorge from 100 to 140 feet deep across the plain. On either side of this valley the plain is broken by a series of hills or dunes ranging from mere undulations in the surface to huge mounds 130 feet high.

GEOLOGIC HISTORY.

Just previous to the closing stages of the last great period of the earth's history preceding the present, when the northern part of North America was covered with the great ice sheet, not unlike Greenland today, Minnesota and North Dakota, as far west as the Missouri River, were deeply buried beneath the great mountain of moving ice. In the region under discussion, a portion of the great Minnesota ice lobe had already found an old drainage basin far be-

neath where the valley of the Red River of the North now lies, and had for centuries been leveling its rugged surface by the powerful action of its slow movements and adding the debris to that already gathered farther north and east and depositing it at its border, forming the great hills of the terminal moraines of the Coteau des Prairies and the Coteau du Missouri.

The close of this important period was marked by a change in the elevation of the land, a change of climate and a gradual melting of the ice back to points farther north; this is known as the retreat of the ice sheet. This was not a sudden or even a continuous melting or recession, but was marked by a succession of pauses. At each pause sufficient time elapsed to accumulate enough debris along the margins so that when another retreat began a row of hills called a terminal moraine marked the line of the last pause. None of these pauses allowed the accumulation of nearly the amount of material that was deposited at the earliest margin.

Seven moraines were accumulated and left by the retreat of the ice sheet before the epoch is reached which determined the surface geology of the Red river valley and the region under discussion. The seventh moraine, known as the Dovre, marked the edge of the ice sheet when its border lay along the line of hills which lies near White Rock, South Dakota, thence extending north and west near Lidgerwood, Lisbon and Milnor, and following in general the course of the Sheyenne River to Devils Lake.

As the ice melted back from the position just described, the water from the melting ice began to fill the basin of the pre-glacial Red River valley. The continued melting of the ice caused the basin to overflow and an outlet, naturally, was formed at the lowest point of the rim. This outlet channel thus formed was that in which Lakes Traverse and Big Stone now lie, and which was the former channel of the Sheyenne River before the last recession of the ice sheet. The great lake which thus began, increased in size as the ice front melted back, until it covered an area nearly as great as that of all of our Great Lakes combined. This lake is called Glacial Lake Agassiz, for a detailed description of which see U. S. Geological Survey Monograph XXV, by Warren Upham.

The action of the wind and waves along the border of the ancient lake formed beach lines like those formed by great lakes today, accumulating sand and gravel in places into great ridges. The cut-

twenty to forty feet deep near the river, but rarely extend back from the river more than a mile or two. At first it seems strange that so young a drainage system should still exist, but this is accounted for by the extreme youth of the region.

The lacustrige deposits, when once started, erode rapidly. In 1895 a wagon road was graded east of the river between sections 30 and 31, Oakport township. (T. 140, R. 48), for a distance of about six miles. The farmers at once began to drain their fields into the ditch made at the roadside. Erosion immediately became active for the full distance of six miles from the river, deepening and broadening the roadside ditch. In a period of four years the water had eroded a channel eighty feet wide and twenty-five feet deep for nearly a mile from the river destroying the road and necessitating the building of substantial bridges.

The Wild Rice and Sheyenne Rivers have their sources outside the Red River valley, and from the places where they enter the level plain of the valley bottom, their channels and meandering courses are not unlike that of the main stream.

The Wild Rice river has its source among the morainic hills near the southern boundary of the state of North Dakota. It enters the valley in eastern Sargent county, crossing the Sheyenne Delta for a distance of twenty-four miles in a direct line. It receives little or no lateral surface drainage in this region. It flows north parallel with the main stream more than forty miles before entering it. In the spring the river is full, but after the June and July rains it often becomes completely dry. The fall rains start the flow again, but the stream freezes to the bottom in many places in the winter.

The Sheyenne is the most interesting stream of the region. Having its source southwest of Devils Lake it flows 180 miles before entering the valley of the Red River of the North. It occupies a valley ranging from one-fourth of a mile to one mile in width and from 75 to 150 feet deep. During the principal period of the existence of Glacial Lake Agassiz the chief source of water besides that coming directly from the ice front came through the Sheyenne River.

This glacial river entered the lake about ten miles southeast of Lisbon, in Ransom county. The amount of sediment brought into the lake was very great and the deposit thus formed is known as the Sheyenne Delta. Upham estimates the area of this delta at 800

Bed of Wild Rice River in Red River Valley, Southeast of Abercrombie.

Bridge Over Sheyenne River at Haggart Station.

square miles, with an average depth of forty feet and volume of six cubic miles. (U. S. G. S. Monograph XXV.)

The position of the Sheyenne Delta is shown on the accompanying maps. The finer clay sediment was carried far out into the lake, leaving the coarser sandy material to form the delta. As the lake receded the vast delta of fine sand was left bare, and the river began to excavate a channel across its own delta. The water which entered the lake during its highest stages and which brought most of the sediment which formed the sediment, was greatly diminished by the diverting of the waters from the melting ice from the sources of the Sheyenne into other channels before the lowering of the lake had reached the fifth stage, or that of the formation of the McCauleyville beach, which shore line marks approximately the outer border of the delta, and before the river had cut a channel across its delta. Had this not been so the delta must have extended further into the valley locally where the valley of the Sheyenne debouches upon the Red River valley in northeast Barrie township.

After entering the valley of the Red River of the North the river takes a serpentine course northeast nearly forty miles before finally entering the Red River of the North. Although the Sheyenne River has a drainage area of over 4,000 square miles above its junction with the Maple yet the stream does not suffer from floods nor seriously endanger the lands along its lower course, for the channel below where it enters the Red River valley lowlands is capable of caring for the water as fast as it descends from the tortuous channel of the upper stream.

During the higher stages of the lake, while it yet had an outlet toward the south, the waters of the Sheyenne, as these entered the lake, drifted southward distributing sediment along the margin of the lake and finding an outlet into the Minnesota River. However, to divert the present Sheyenne River and to make it discharge its water into Big Stone Lake and the Minnesota River, as it once did, and as has been advocated as a measure to prevent floods in the Red River valley, is entirely impracticable as the old channel is 150 feet above the present stream.

As the Sheyenne entered the Red River valley during and immediately following the McCauleyville stage of the lake it doubtless took a course almost directly east. Evidences of this old course are still marked first by the sharp bend of the stream to the east as it

enters the valley in the southeast corner of section 11, Barrie Township, and second, following the course of the river after it turns to the north the old channel is again marked on sections 8, 9, 10 and 14, Walcott Township. The volume of water could not have been great, else the first channel had kept open. The extreme level character of the land made it easy for the waters to be diverted northward, whence it flows more than thirty miles almost parallel with the Red River of the North.

Along the Sheyenne valley occur a number of springs which usually keep it flowing during the summer months, however, it has been known to become completely dry. It is noticeable that the stream has almost no tributaries, and where the valley crosses the sandy plain of its delta it is rare that any surface drainage for more than a mile from the stream ever gets into the river. It is believed that were it not for the great channel, eroded by the glacial waters, the greater part of the 4,000 square miles of its drainage area would be like the Devils Lake region and a large area between the Sheyenne and James Rivers, an area of undeveloped drainage.

The Maple River has its origin and course developed in much the same manner as the Sheyenne. The drainage area is much less, its valley not so deep. Like the Sheyenne and other tributaries of the Red River of the North it turns northward after entering the valley. It unites with the Sheyenne ten miles above where their combined waters enter the Red River of the North. During dry years the bed is usually almost or entirely without water.

In connection with the Maple River is a peculiar topographic feature. Beginning at the east side of section 19, Maple River Township, Cass county, is a serpentine ridge from fifteen to twenty-five feet high, following in general the course of the Maple River. It is plainly traced for a distance of twenty miles. It can hardly be in any way connected with a beach line of the retreating lake, for the ridge originates with its crest 945 feet above tide and seems to be independent of the general topography, the lower part of the crest being not over 910 feet above tide. Across Maple River township the ridge contains much sand, and several sand and gravel pits have been opened. There is in each case less than five feet of sand and gravel. As the ridge is traced farther north across Durbin, Harmony and Raymond townships, it offers attractive sites for farm buildings, but in nearly every case in drilling or boring for water.

Island Park, Fargo, Showing Flood of 1897.

Red River of the North at Pembina, Showing Ferry.

quicksand is struck from twelve to eighteen feet below surface, which is rarely penetrated far. The ridge follows closely the general course of the Maple River. It contains coarse materials near its origin and quicksand along the balance of its course. It is independent of the natural topography. Its origin is near where the Maple River makes its debouchure into the level valley bottom. All this leads to the belief that it was formed by the Maple River entering comparatively shallow water, dropping its coarser materials first and the fine quicksand in the more gently moving current farther out from shore. It acts in every respect like what would be called an esker or osar in glaciology, but what could confine a stream of water in a shallow lake in one course long enough to deposit such a prominent ridge is not clear.

SOIL SURVEY OF THE GRANK FORKS AREA, NORTH DAKOTA.

By Charles A. Jensen and N. P. Neill.

(Reprint from Field Operations, Bureau of Soils, 1902.)

LOCATION AND BOUNDARIES OF THE AREA.

The area surveyed is situated in Grand Forks county, one of the eastern tier of counties of North Dakota, lying a little north of the east and west medial line. The eastern limit of the area is the Red River of the North, which also forms the state boundary line. Grand Forks, in the northeastern part of the area, is situated in about north latitude forty-seven degrees, fifty-five minutes and west longitude ninety-seven degrees, five minutes. The area extends a distance of thirty-four miles west from that town. For the first fifteen miles the area is six miles wide, and for the remaining eighteen miles it has a width of twelve miles. The area includes township 151 north, ranges 50 to 55 west, inclusive, and township 150 north, ranges 53 to 55 west, inclusive, and covers an area of 314 square miles or 200,960 acres. Probably most or all of the types of soil in the county occur in the area mapped.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The Dakotas were originally a part of Michigan, Wisconsin, Iowa and Minnesota, and during the years between 1834 and 1858 the

boundaries were often changed. Civil government of the Dakotas did not begin until 1861, and North and South Dakota were not constituted separate states until 1889.

British and American fur companies were the first to occupy Dakota territory, and land was not taken up for agricultural purposes until 1851, when a few white settlers obtained a few hundred acres from the Sioux Indians. Agricultural pursuits were, however, often interrupted, even at this late date, by the Indians, who a number of times drove the settlers out of the country.

Grand Forks county was created June 4, 1873, from part of Pembina county. Its boundaries were changed in 1875, in 1881, and again in 1883. The first settlement in the county was Grand Forks, the county seat, which was established late in the seventies. What was but an aggregation of a few houses in 1879 is now a thriving town of 8,000 or 9,000 inhabitants. Agricultural development at that time was limited to a few isolated ranches, as there were no railroad accommodations so far north until 1880-81, when the Great Northern railway was built through Grand Forks westward. Agricultural development was very rapid along the main line of this road and branches were soon built which gave greatly increased shipping facilities and resulted in a great impetus to farming in various parts of the county and state.

The increase in improved farm lands has, however, been greatest during the last decade, within which time the number of farms and the value of improvements have almost doubled. Much of the western part of the county is not yet improved or developed, being somewhat hilly and less desirable generally than the eastern part.

CLIMATE.

The climate of the Red River valley may be classed as subhumid. The annual rainfall, which is approximately twenty inches, is usually so distributed as to furnish enough moisture for crop purposes during the growing season. Occasionally, however, a season of drought occurs when crops are practically a failure. The year 1902 was very favorable as regards moisture, but the spring season was late and in a few instances cereals could not be planted in time to mature. The summer months are warm without being uncomfortable, and the fall months cool—conditions required for the proper maturing of the hard variety of wheat grown.

Hailstorms sometimes do considerable damage, and a few of these occurred in various parts of the state in 1902. A small section of the county sustained damage in July by a hailstorm, the force of the wind being sufficient to upset a few houses and telegraph poles.

The wind movement is comparatively high, especially during the fall of the year. It is sometimes strong enough during the summer months to badly damage heavy grain, especially if the wind is accompanied by rain, as sometimes happens.

The following table shows the normal monthly and annual temperature and precipitation, taken from the weather bureau records:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Larimore		University	
	Temperature—degrees F.	Precipitation—Inches	Temperature—degrees F.	Precipitation—inches
January	4 0	0.91	4.0	0.55
February	5.0	.31	6.0	.51
March	17.0	.55	19.0	.62
April	41.0	1.47	41.0	2.88
May	53.0	2.54	54.0	3.14
June	60.0	3.68	63.0	4.32
July	66.0	3.35	67.0	1.96
August	64.0	1.97	....	1.94
September	56.0	.61	56 0	1.12
October	42.0	.79	42.0	.76
November	22.0	.36	22.0	.76
December	18.0	.75	10.0	.62
Year	38.0	17.25	....	19.64

PHYSIOGRAPHY AND GEOLOGY.

The topography of the area is very simple. The level alluvial area extends from Grand Forks west to within about two miles of Emerado. The slope of this area is less than one foot to the mile. From there westward to the glacial drift there are eight or ten beaches or ridges with a northwest and southeast trend, varying in height from a few feet to perhaps forty or fifty feet, though the latter height is seldom attained in the area surveyed. These ridges are from one-half mile to two or three miles apart and have very gentle slopes. Often shallow swales extend from one beach to another. Sometimes the beaches form plateaus.

From the Herman beach westward as far as the area surveyed extends there is a rise of perhaps 100 to 200 feet. This is the glacial drift area and consists almost entirely of small hills and hollows

or swales scattered about indiscriminately. The individual hills are not extensive in area and vary from ten feet to sixty or seventy feet in height, with slopes generally not too steep for cultivation.

There are many glacial bowlders scattered about these hills and in the whole of the western part of the area surveyed. These occur in small masses or singly, and some of them are of enormous size. They are, however, not numerous enough to interfere seriously with cultivation.

There are a number of stream courses, a few deep but most of them shallow, traversing the area in a generally easterly direction. With few exceptions these are dry during the greater part of the year.

The area surveyed includes a part of the bed of glacial Lake Agassiz, and extends from Red River (approximately the middle of the valley), to and slightly beyond the upper or western beach of the lake into the glacial drift. The area thus traverses the lacustrine deposits in the middle of the valley, the bench lands and beaches westward, and the upper beach of the lake. The extreme western limit of the area extends several miles into the glacial drift, which corresponds to Fargo gravelly loam. The altitude of Grand Forks is 830 feet above sea level.

The upper beach, several miles west of Larimore, known as the Herman beach, marks the western limit of the lake, while from there to several miles east of Emerado is a series of smaller beaches, representing various temporary stages of the lake during its recession. There are smaller unimportant beaches between Ojata and Grand Forks. These beaches consist of sandy loam, sand and gravel, and reworked till, the surface soil being invariably sandy loam, generally gravelly. Some portions of these beaches, especially those near the western limit of the lake, closely resemble eskers. These beaches were undoubtedly formed by the action of the surf of the lake while its waters remained at one level for longer or shorter periods, in the same manner that beaches are formed at present along the shores of existing bays and lakes. The formation of the beaches was also assisted by the debris continually being unloaded by the floating ice. The coarser material would thus be washed up along these beaches and the finer particles, with occasional pebbles, would settle in the swales between them.

Small kettle holes are quite numerous in the western part of the area and more rarely in the eastern.

The alluvial clay proper, or as classified during the survey, Miami black clay loam, does not appear along the main line of the Great Northern railway until a point about two miles west of Ojata is reached, while west of this the surface soil is sandy loam with a clay or clay loam subsoil. The alluvial silty loam, grading into clay or clay loam at a few feet below the surface, varies considerably in depth and at Grand Forks is probably from fifty to seventy-five feet deep. This stratified alluvial deposit is underlain by glacial till or drift, which gradually approaches the surface westward, forming the subsoil of Fargo gravelly loam and finally outcropping a few miles west of Larimore as a beach. At Fargo the drift has a thickness of 150 feet. Under this drift is found cretaceous shale, probably the Niobrara and Fort Benton. It has a thickness at Grand Forks of over 300 feet. This is in turn underlain, at a depth of 385 feet at Grand Forks, by granite and gneiss which extends to an unknown depth.

Over a large part of the area, especially in the west, large bowlders of granite, gneiss, and more rarely limestone are found in local masses, having been dropped by the floating ice. A large number of local beds of crystalline gypsum were found at a depth of from one to six feet below the surface. Apparently similar beds were also found in the glacial drift.

As gypsum beds are found almost invariably in the slight local rises or ridges in the alluvial soils, and as the texture of the soil in those places is lighter than the surrounding soils, it would appear that these beds are due to gypsum and accompanying salts being dropped there by the floating ice. Against this theory may be urged the fact that bowlders are not found in or around these local rises. Bowlders of fair size are, however, found at a considerable distance east of Ojata, and as gypsum has a lighter specific gravity than granite or limestone, there would at least be a chance of its being carried farther by the smaller floating ice masses. Moreover, the lake must have been comparatively shallow at the time these gypsum beds were laid down, for over some of them there is less than a foot of soil. With the lake at a low stage it would be impossible for large ice masses carrying great bowlders to drift so far eastward.

SOILS.

Five types of soil were recognized in the area surveyed: Fargo gravelly loam, Miami sandy loam, Fargo loam, Miami loam and Miami black clay loam. Besides these types a number of small areas of muck were mapped.

The texture of the surface soils in the eastern part of the areas is as a rule heavier than in the western, the difference being due to the difference in origin. Those in the eastern part of the area are of direct alluvial origin and are loams or clay loams, while those in the western part have been more or less modified by the action of the shore water of the ancient lake and by drift and are consequently lighter in texture.

AREAS OF DIFFERENT SOILS

Soil	Acres	Per cent	Soil	Acres	Per cent
Miami sandy loam	68,800	34.3	Fargo loam	12,352	6.1
Fargo gravelly loam	51,136	25.4	Muck	6,592	3.3
Miami black clay loam	44,352	22.1			
Miami loam	17,728	8.8	Total	200,960	

FARGO GRAVELLY LOAM.

The Fargo gravelly loam, occupying, as typically developed, the extreme western limit of the area, consists of from one to two and a half feet of loose black sandy loam with small gravel disseminated through it varying in size from very small particles to pebbles about one-half inch in diameter. The surface is also generally gravelly, though over large areas this feature is absent. The surface soil is underlain to a depth of about three feet by a black or gray gritty loam, which is in turn underlain by gritty, stiff white or yellow, or mottled gray and yellow loam, containing small gravel and frequently small concretions of iron oxide. This material often grades into clay loam or clay at a depth of five or six feet. Local beds of crystalline gypsum are often found at a depth of two or three feet. Over the surface are scattered local masses of glacial bowlders of granite, gneiss, schists and limestone, but these are not numerous enough to seriously interfere with cultivation.

The topography is undulating, consisting of small irregular hills or knolls of small surface area varying in height from about ten feet to forty or fifty feet. Between these are shallow depressions in the shape of swales or kettle holes. The slopes of these hills are

not steep and with very few exceptions are easily cultivated. The soil on their summits is lighter in texture than that of the intervening hollows and contains considerable gravel, while the surface soil in the depressions is often very mucky, though not sufficiently pronounced to be classed as muck.

This type is well drained, with the drainage eastward, and many shallow and a few deep creek depressions traverse it, the majority of which, however, are dry during the greater part of the year.

A few local alkali spots were found in this soil, but none of great enough extent to show on a map of the scale used. The clay and clay loam subsoil generally carry some and often considerable alkali, but this does not lie near enough to the surface to interfere with plant growth. The subsoil often carries a very large amount of lime and when mixed for tests in alkali determinations it gives off a strong mortarlike odor. The lime is probably due to limestone which has been crushed and ground by the ice, as small gravel of this rock of all sizes is scattered through the soil.

The Fargo gravelly loam is largely composed of glacial till or drift, though in the eastern limit of the type the material has been reworked by the wave action of the ancient lake. The soil there gives evidence of having been considerably washed, and hence there is much more gravel and the interstitial soil is lighter than in the area farther west.

This soil is generally adapted to wheat, oats and barley, and during seasons of favorable rainfall good yields of these crops and of flax can be produced. The soil on the higher elevations does not, however, retain moisture well and is apt to be affected by drought.

Much of this type is still unbroken and unimproved and such areas bear a splendid growth of prairie grass and would be excellent for grazing range stock.

A valley phase of the Fargo gravelly loam consists of from one to six inches of black, sometimes mucky, sandy loam, often containing small gravel, underlain to a depth of two feet by a gritty black or gray loam containing small pebbles up to one-half inch or so in diameter. This is in turn underlain to a depth of six feet by a gritty, stiff, mottled gray and yellow clay loam or clay, interspersed with small gravel and usually with small concretions of iron oxide. Sometimes the sixth foot, especially in the eastern part of the area, becomes a silty loam of the same material as the subsoil

The Miami sandy loam is well drained and free from alkali and is generally well adapted to wheat, oats, flax and barley. Owing, however, to the light and loose texture of the surface soil, of some of the areas a plentiful supply of rain is necessary to insure good crops. The beaches are generally too light and loose in texture and often too gravelly to be of any value for agriculture.

This is the only type in which gypsum beds were not found at some depth or other.

Below are given the mechanical analyses of this soil:

MECHANICAL ANALYSES OF MIAMI SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.05 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7452	W. center sec. 23, T. 151 N., R. 54 W..........	Sandy loam, 0 to 12 inches..................	2.79	0.76	3.86	6.88	56.32	6.38	18.91	5.90
7455	Center NW. ¼ sec. 24, T. 151 N., R. 55 W...	Sandy loam, 0 to 12 inches..................	3.59	.10	1.32	3.32	50.76	14.22	18.30	11.10
7453	Subsoil of 7452..........	Sandy loam, 24 to 36 inches..................	1.22	.64	3.90	7.60	68.91	5.58	5.52	7.02
7454	Subsoil of 7452..........	Sandy loam, 48 to 60 inches..................	.72	2.46	9.20	8.24	55.70	6.34	8.60	9.12
7456	Subsoil of 7455..........	Heavy sandy loam, 24 to 36 inches..........	.86	.24	.88	3.12	43.56	14.32	14.54	22.60

FARGO LOAM.

The Fargo loam consists of about six inches of black sandy loam of the same character as the surface soil of the Miami sandy loam, underlain with black loam or light clay loam to a depth of one and half feet. Beneath this, to a depth of two feet nine inches, is a fine gray, sometimes silty, loam containing no appreciable amount of grit and very much like the corresponding section of the Miami black clay loam. This stratum is in turn underlain to a depth of six feet with a fine sandy, usually silty, loam, which is generally mottled, contains small concretions of iron oxide, and is of a gray and yellow color below the fourth foot.

Small beds of gypsum often occur in the second foot, but owing no doubt to the light subsoil there is usually no excess of alkali in the first three feet.

The drainage of this soil is usually good, and the type is almost

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a mottled gray and yellow stiff, gritty loam or clay loam, containing a large proportion of small gravel. Usualy small concretions of iron oxide are present in the soil below the fourth foot. This subsoil is much like the corresponding section of Fargo gravelly loam and, like it, carries local beds of gypsum.

The Miami sandy loam is well drained and free from alkali and is generally well adapted to wheat, oats, flax and barley. Owing, however, to the light and loose texture of the surface soil, of some of the areas a plentiful supply of rain is necessary to insure good crops. The beaches are generally too light and loose in texture and often too gravelly to be of any value for agriculture.

This is the only type in which gypsum beds were not found at some depth or other.

Below are given the mechanical analyses of this soil:

MECHANICAL ANALYSES OF MIAMI SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.05 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7452	W. center sec. 23, T. 151 N., R. 54 W.	Sandy loam, 0 to 12 inches	2.79	0.76	3.86	6.88	56.32	6.38	18.91	5.90
7455	Center NW. ¼ sec. 24, T. 151 N., R. 55 W.	Sandy loam, 0 to 12 inches	3.59	.10	1.32	3.32	50.76	14.22	18.30	11.10
7453	Subsoil of 7452	Sandy loam, 24 to 36 inches	1.22	.64	3.90	7.60	68.91	5.58	5.52	7.02
7454	Subsoil of 7452	Sandy loam, 48 to 60 inches	.72	2.46	9.20	8.24	55.70	6.34	8.60	9.12
7456	Subsoil of 7455	Heavy sandy loam, 24 to 36 inches	.86	.24	.88	3.12	43.56	14.32	14.54	22.60

FARGO LOAM.

The Fargo loam consists of about six inches of black sandy loam of the same character as the surface soil of the Miami sandy loam, underlain with black loam or light clay loam to a depth of one and half feet. Beneath this, to a depth of two feet nine inches, is a fine gray, sometimes silty, loam containing no appreciable amount of grit and very much like the corresponding section of the Miami black clay loam. This stratum is in turn underlain to a depth of six feet with a fine sandy, usually silty, loam, which is generally mottled, contains small concretions of iron oxide, and is of a gray and yellow color below the fourth foot.

Small beds of gypsum often occur in the second foot, but owing no doubt to the light subsoil there is usually no excess of alkali in the first three feet.

The drainage of this soil is usually good, and the type is almost an ideal one for an alkali district, as the light subsoil allows the alkali to be carried away by the underground water, while the surface soil is heavy enough to retain moisture well.

This soil occupies the slight depressions and shallow swales found in the Miami sandy loam area, and owes its origin partly to transportation of the finer particles from the higher lying sandy loam areas, although chiefly to lacustrine deposit during the early period of the recession of the glacial lake.

The soil is well adapted to wheat, oats, flax, barley and corn. As its ability to retain moisture is greater than that of the lighter soils it withstands drought better and crops are somewhat surer on this account.

The following table shows the mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF FARGO LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7457	¼ mile E. of NW. corner sec. 15, T. 150 N., R. 54 W.	Light loam, 0 to 12 inches	6.28	Tr.	1.60	3.30	39.74	15.74	25.50	13.54
7459	Subsoil of 7457	Light sandy loam, 48 to 60 inches	.79	0.20	.94	2.44	50.50	20.24	14.66	10.72
7458	Subsoil of 7457	Loam, 24 to 36 inches	1.60	.00	.98	3.14	40.38	15.74	16.78	22.2

MIAMI LOAM.

The Miami loam consists of from one to two feet of black to brown sandy loam of the same texture as the material composing the surafce soil of the Miami sandy loam. This material, without change in texture, grades into a yellow-colored soil beneath which occurs about one foot of gray or white gritty loam, often containing small gravel. This is in turn underlain to a depth of six feet with a mottled gray and yellow stiff, gritty loam or clay loam, containing a large proportion of small gravel. Usualy small concretions of iron oxide are present in the soil below the fourth foot. This subsoil is much like the corresponding section of Fargo gravelly loam and, like it, carries local beds of gypsum.

There are rarely large enough areas containing excessive amounts of alkali in the first three feet of the soil of this type to be indicated on a map of the scale used; that is, there is generally less than the minimum limit of 0.20 per cent. The subsoil, however, usually contains some alkali and often the amount is considerable.

This soil is found on the slopes of the eastern beaches of the old lake and in intervening areas, being typically developed at Emerado. The sandy loam surface is due to transportation and deposition of material carried over the beaches by the water during the recession of the lake. Some of the areas of the type owe their origin to transportation of sandy loam and sand from the top of the beaches into the swales between them, the sandy loam being really a covering over the Fargo gravelly loam.

The typical areas of this type are well adapted to wheat, oats, barley, millet and flax, though the lower-lying areas of the type, where the alkaline subsoil is near the surface, do not produce very good crops.

The following table gives mechanical analyses of this soil:

MECHANICAL ANALYSES OF MIAMI LOAM

No.	Locality	Description	Organic matter per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 3.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7437	¼ mile S. of NE. corner sec. 2, T. 151 N., R. 52 W.	Sandy loam, 0 to 18 inches	5.74	1.68	4.74	9.12	12.16	20.64	41.12	10.54
7438	Subsoil of 7437	Loam or clay loam, 48 to 60 inches	.47	2.5	3.90	3.96	10.74	9.34	48.14	21.42

MIAMI BLACK CLAY LOAM.

The Miami black clay loam consists of from one inch to four or five inches of muck or mucky loam underlain with black loam, often of a silty texture, to a depth of from one to two feet. Beneath this is about a foot of fine gray, usually silty, loam that nearly always grades into yellow silt loam at about three feet below the surface. This is in turn underlain to a depth of six feet with a mottled gray and yellow silty loam, sometimes becoming a silty clay loam in the

fifth or sixth foot. Almost invariably small concretions of iron oxide occur in the soil below the third foot. It is this iron that gives the soil its usual yellow color when a depth beyond the influence of dissolved organic matter is reached. The type is very fine in texture and usually does not contain a noticeable amount of sand. Local beds of crystalline gypsum often occur and are found at any depth in the profile.

For a distance of several miles west of Red River there is in the surface three feet of the Miami black clay loam very little alkali, but farther west, as far as the type has been mapped and especially around Ojata, where the natural drainage is poor, the amount of alkali is considerable. Black alkali was almost invariably found in both the surface soil and subsoil, the quantity varying from a trace to 0.05 per cent in the surface foot and usually a little less in the subsoil. The black alkali is, of course, not found in areas with free gypsum beds. There was also very often less than 0.20 per cent of soluble salt in the first three feet in these places.

Excepting the alkali areas, the Miami black clay loam is generally recognized as being a fine soil for wheat, oats, barley and flax. The type very well withstands moderate drought, the subsoil being always in fine, moist condition. It would be an excellent soil for celery in seasons of good rainfall.

The area over which this soil occurs is very level, broken only by a few shallow creek depressions which do not at all interfere with cultivation. (See figure OO.)

This soil is a lacustrine deposit and is the only type in the area that has not been modified by other action since the original deposition.

The following table shows the texture of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm.—per cent	Coarse sand 1 to 0.5 mm.—per cent	Medium sand, 0.5 to 0.25 mm.—per cent	Fine sand, 0.25 to 0.1 mm.—per cent	Very fine sand, 0.1 to 0.05 mm. per cent	Silt, 0.05 to 0.005 mm. per cent	Clay, 0.005 to 0.0001 mm. per cent
7442	W. center sec. 36, T. 151 N., R. 51 W.	Loam, 0 to 12 inches	5.67	0.00	0.20	0.20	1.66	17.10	75.04	4.94
7439	N. center sec. 91, T. 151 N., R. 52 W.	Loam, 0 to 12 inches	4.02	.36	1.14	1.22	3.56	5.70	64.78	22.98
7443	Subsoil of 7442	Silty loam, 24 to 36 inches	.65	.12	.54	.40	.70	9.36	83.82	4.18
7444	Subsoil of 7442	Silty loam, 48 to 60 inches	.46	.0	.36	.30	.56	3.22	79.78	14.82
7440	Subsoil of 7439	Silty loam, 24 to 36 inches	.79	.20	.72	.38	.68	4.06	77.42	16.34
7441	Subsoil of 7439	Silty loam, 48 to 60 inches	.53	.16	.60	.50	1.00	2.70	73.12	21.68

MUCK.

The muck soil is found in many places in different parts of the area, the individual areas varying in size from an acre or less to about one square mile. The type consists of from one to three feet of muck, underlain by sandy loam or sand or, rarely, by loam. This is in turn underlain by sandy loam to a depth of six feet.

Muck is found in local depressions, such as kettle holes and swales and generally along the creek courses and in swamps. It is due to gradual accumulation and decomposition of organic matter resulting from the rank grasses which in this area appear to be about the only vegetation growing in these swampy places. In the spring of the year the areas are usually wet and swampy, but during summer they become dry enough to allow the cutting of the grasses for hay.

No alkali exists in this type, its absence being chiefly due to the the light subsoil, as, aside from percolation downward, these areas are usually poorly drained.

UNDERGROUND WATER.

No general relation seemed to exist between the salt content of the soil and the water table, except where the latter was within three feet or so of the surface, when there was generally a noticeable increase of salt in the surface foot of soil.

The following table shows the results of field analyses of well waters in all parts of the area. With but few exceptions the shallow wells contained less soluble salts than the deeper, and especially the flowing wells. The alkali content of the last ranged from 420 to 1,430 parts of soluble salt per 100,000 parts of water, the salts consisting mostly of chlorides, with sulphates second. The deep and the flowing wells generally contain less of the bicarbonates than the shallow wells.

CHEMICAL ANALYSES OF WELL WATERS

No. of sample	Location	Depth in feet	Parts of salt per 100,000			
			Total salt content	Bicarbonates	Chlorides	Sulphates [a]
14	¼ mile E. of SW. corner sec. 8, 151 N., R. 51 W	....	250	49	12	189
15	N. center sec. 7, T. 151 N., R. 50 W	(*b*)	540	42	276	212
52	NE. corner sec. 16, T. 1 1, N., R. 50 W	(*b*)	420	38	260	122
52½	Same place as sample 52	5	55	(*c*)	(*c*)	(*c*)
59	SW. corner sec. 2, T. 151 N., R. 50 W	6	130	89	9	32
80	¼ mile N. of SW. corner sec. 34, T. 151 N., R. 50 W	75	90	(*c*)	(*c*)	(*c*)
81	¼ mile W. of SE. corner sec. 34, T. 51 N., R. 50 W	7	40	(*c*)	(*c*)	(*c*)
91	⅛ mile W. of NE. corner sec. 11, T. 150 N., R. 50 W	....	130	67	5	58
93	W. center sec. 3, T. 150 N., R. 50 W	....	90	(*c*)	(*c*)	(*c*)
106	NE. corner sec. 32, T. 151 N., R. 50 W	7	55	(*c*)	(*c*)	(*c*)
171	S. center sec. 6, T. 150 N., R. 54 W	12	170	63	Tr.	107
178	N. center sec. 11, T. 151 N., R. 55 W	16	28	(*c*)	(*c*)	(*c*)
183	NE. corner sec. 4, T. 151 N., R. 55 W	15	60	52	7	None
190	⅛ mile E. of SW. corner sec. 17, T. 151 N., R. 55 W	40	250	53	64	133
209	NE. corner sec. 33, T. 151 N., R. 55 W	18	60	58	3	None
215	NE. corner sec. 29, T. 151 N., R. 55 W	15	360	50	58	252
217	NE. corner sec. 31, T. 151 N., R. 55 W	9	320	[illegible]	58	212
227	SW, corner sec. 33, T. 151 N., R. 55 W	10	170	67	21	82
230	¼ mile E. of SW. corner sec. 5, T. 150 N., R. 55 W	60	180	71	21	88
245	SE. corner sec. 34, T. 151 N., R. 55 W	....	220	60	21	139
316	SE. corner sec. 25, T. 150 N., R. 54 W	8	135	58	3	74
334	SE. corner sec. 26, T. 151 N., R. 53 W	10	135	78	12	45
354	⅛ mile N. of SE. corner sec. 1, T. 151 N., R. 54 W	....	465	87	12	366
374	E. center sec. 12, T. 151 N., R. 54 W	150	560	63	7	490
397	S. center sec. 23, T. 151 N., R. 53 W	9	180	73	23	None
420	¼ mile S. of NW. corner of sec. 4, T. 150 N., R. 53 W	9	250	55	Tr.	195
450	N. center sec. 11, T. 151 N., R. 52 W	9	110	53	63	None
456	¼ mile W. of NE. corner sec. 1, T. 151 N., R. 52 W	(*b*)	490	42	290	158
473	S. center sec. 16, T. 151 N., R. 52 W	4	340	52	16	272
493	SE. corner sec. 24, T. 151 N., R. 52 W	*b*33	560	42	302	216
335	SE. corner sec. 26, T. 151 N., R. 53 W	80	130	80	12	38
519	SE. corner sec. 27, T. 151 N., R. 52 W	*b*130	520	73	358	89
529	N. center sec. 35, T. 151 N., R. 52 W	*b*44	420	53	202	165
533	¼ mile W. of SE. corner sec. 11, T. 151 N., R. 52 W	(*b*)	430	50	81[illegible]	567
536	NE. corner sec. 13, T. 151 N., R. 52 W	6	70	50	14	None
564	SW. corner sec. 30, T. 151 N., R. 51 W	*b*135	660	45	441	174
578	N. center sec. 1, T. 151 N., R. 51 W	....	720	50	346	324

a Sulphates computed by taking the difference between total salt content and bicarbonates and chlorides.
b Flowing.
c Quantity not determined.

ALKALI IN SOILS.

The map showing the alkali in the soil, departs from the general rule of such maps previously made for areas lying in irrigated and arid regions in one particular, viz, it is based upon the mean amount

of salts in the first three feet of soil instead of upon the mean in the first six feet. The difference in climatic conditions and the fact that shallow-rooted crops form almost exclusively the agriculture of the area made it seem unnecessary to use the more extended profile in this case. It is even thought that a map based on the shallower borings will be of greater value than one where the deeper subsoil was taken into the calculations.

In the Grand Forks area there is generally enough precipitation to prevent the salt in the subsoil from lodging permanently in the surface soil through capillary action, and the roots of the crops commonly grown do not usually, perhaps never, reach deeper than three feet. The fact that alkali below this depth, or even at two or three feet, can have little or no effect on the crop growth was conclusively proved by the condition of the crops seen during the survey. Irrigation is not practiced in the areas, and probably never will be extensively practiced, so that the vertical distribution of the salts will not, as in other alkali areas, be affected artificially, and as long as the present method of farming continues in the area there seems no probability that the salts in the subsoil will rise.

A number of determinations were made, however, to depths of six and of eight feet, for the purpose of studying the vertical distribution of the salts in the subsoil. No alkali was found in the Miami sandy loam, even at a depth of six feet, and not enough in the first three feet of Fargo gravelly loam to map, though considerable quantities were present in the subsoil. The conditions in the case of the Miami loam were similar to those of the Fargo gravelly loam, as typically developed, and in these two types alkali would have been much more general had the salt map been based on the mean of six-foot borings instead of three-foot borings, and the conditions would have apparently been much worse than they actually are. Very little alkali was found in the Fargo loam in the first three feet, and none was found in the subsoil, as this was much lighter in texture than the soil.

The two types containing injurious amounts of alkali in the first three feet, as well as in the deeper soil, are the Miami black clay loam and the valley phase of the Fargo gravelly loam. As shown by the alkali map, the greater part of these two soils carry an average of more than 0.20 per cent of soluble salt at soil saturation in the first three feet, and if the map had been constructed to six feet

the conditions would have appeared worse in practically all parts of these areas.

The worst alkali conditions were found in township 151 N., ranges 51 and 52 W. This includes most of the strictly lacustrine deposit soils, as the surface soils west of Emerado have been modified by secondary deposits since the lacustrine subsoil was laid down.

Two ways suggest themselves in which the alkali may have originated. It may have reached the surface by the capillary movement of the salt-carrying, deep-seated waters percolating the underlying drift or Cretaceous shales, assisted by the natural pressure to which these substrata are subjected, or it may have been deposited with the lacustrine material either by being in solution in the lake water, which may have been concentrated, or as being originally in the soil washed into the lake. It does not appear that the lake water ever reached a high state of concentration and this theory is hardly likely, the origin of the lake considered.

The soil borings can be of little value in determining the origin, except so far as they show the constitution of the alkali. Considerable information on this point is obtained by a study of the table of analyses of well waters given on a preceding page. It is undoubtedly fair to assume that the relation of the salt constituents in the well waters agrees approximately with the solution in the soil from which the water is derived.

The chemical analysis of the standardization solution made in the Bureau laboratory conclusively shows the great preponderance of the acids to be sulphates, these constituting, in fact, more than half of the total amount of salts, with chlorides second, but by no means in large quantities. This solution represents all depths of alkali soils from surface crusts to soil six feet below the surface. The various titrations made on soil samples in all parts of the area by the party in the field also brought out the fact that sulphates were generally in excess of any other salt. An inspection of the table of well-water analyses will show that the shallower wells, with but very few exceptions, show sulphates greatly in excess of chlorides.

As no method for the determination of sulphate quantitatively in the field has been devised, these were estimated by difference. The total amount of salt, the chlorides, the carbonates, and the bicarbonates were determined electrically and volumetrically, and it was assumed that the difference between the total amount of salt

and the sum of the other constituents mentioned was equal to the sulphates. The results of this method are not, of course, strictly accurate, but are sufficiently so for the purpose of discussion, as no other salts were reported in the complete chemical analyses made in the laboratories.

By referring to the above mentioned table it will be seen that the chlorides and sulphates occur in altogether different relation in the deeper wells, and especially in the flowing wells, than they do in the shallower wells, i. e., wells with a depth of twenty feet or so. There are apparently exceptions, as for instance in Nos. 230 and 335, but as the surface water was not excluded from the deeper seated strata these are of no consequence. The chlorides are in every instance in excess of the sulphates in these deep wells, while in the shallower wells the sulphates are largely in excess. Considered along with this that beds of sulphates, especially gypsum, are quite numerous in the lacustrine deposit and distributed over the entire lacustrine area—Miami black clay loam and valley phase of the Fargo gravelly loam—one cannot but conclude that the alkali in the alluvial area in the surface soils was deposited with the soils at the time these were laid down in the lake, and that the alkali water from the deeper and flowing wells belongs to another formation probably the underlying Cretaceous shales.

With but few exceptions the quantity of salt was found to increase downward. The maximum found was about three per cent in the dry soil, and in the worse alkali districts this quantity was found at from three to six feet. No maximum was found in any one particular foot section, but when once the three per cent was reached there was no diminution.

Black alkali was very often, in fact generally, found, even in the presence of small amounts of sulphates, in both soil and subsoil. It was particularly likely to occur in the surface foot, the amounts varying from a trace to 0.07 per cent, though this latter figure was reached in but one place. As much as 0.05 per cent was found in a number of places, but the distribution was not sufficiently extensive or general to warrant the construction of a separate black alkali map.

Good crops of grain, flax, and millet were often found growing on the alkali soils, even where the average amount of salt in the first three feet ranged from one to three per cent. This was due

often to the unequal vertical distribution of the alkali, the surface foot carrying but a small part of the total amount. In arid regions such amounts of alkali would with certainty kill any but the most resistant salt grasses, and some areas where most vegetation had succumbed were found in the area surveyed, while in the worst alkali district, in and around Ojata, bare spots were common, these containing a surface deposit of alkali, where even salt grasses and alkali weeds could not exist. However, very fair crops were found to be growing even where the surface foot carried what would usually be considered excessive amounts of salt for agricultural crops.

The table on the following page, while not intended at all to define the exact salt conditions under which crops will or will not grow, shows at least conditions as found in the area surveyed.

TABLE SHOWING THE RELATION OF THE CONDITION OF GROWING CROPS TO THE PERCENTAGE OF ALKALI IN THE FIRST FOOT OF SOIL IN THE GRAND FORKS AREA

Crops	Condition			
	Good Crop	Fair Crop	Poor Crop	Killed
	Per cent	Per cent	Per cent	Per cent
Wheat	0.30	....	....	0.56
	.39	....	....	.76
	.46	....	....	....
Oats	.39	0.58	0.63	....
	.46	....	.84	....
	.51	....	....	....
Barley	.31	.44	.70	....
	.43	.46	....	....
Flax	.32	.37	.52	.56
	.38	.55	.64	.80
Prairie grass and salt grasses	1.16	1.50	....	....
	1.20	2.00	....	....

There are, of course, different crop conditions with the same salt content in the surface foot of soil, as many factors enter into discussion, such as late or early seeding, presence or absence of favorable proportion of moisture in the soil, etc. As these conditions were found in the fall of the year when the crops were matured there can be no doubt about the observations. It should also be kept in mind that in every instance the salt content increased in lower depths, the third foot section carrying more than one per cent of alkali in some cases where good crops were growing.

There is but one way to reclaim the alkali flats so that they will grow agricultural crops profitably, viz, by draining them artificially.

The subsoil is too heavy in all places to accomplish drainage otherwise. The alkali area in and around Ojata could be drained into the swamps and shallower creek beds or sloughs found there. It would, however, involve quite an outlay of capital, and under present agricultural conditions would probably not be profitable. The drains, however, would not need to be laid as deep as in the more arid regions, as the greater rainfall washes the salts down from the surface and it is not necessary to control accumulation through evaporation. These alkali flats are, however, valuable even in their present condition, as the native grasses growing on the greater part of them make very good hay when properly cured.

CHEMICAL ANALYSES OF ALKALI SOILS AND CRUSTS

Constituent	7460. ¼ mile E. of University; alkali crust.	7461. ¼ mile W. of NE. corner sec. 12, T. 151 N., R. 51 W., alkali crust.	7462. ¼ mile W. of NE. corner sec. 12, T. 151 N., R. 51 W., subsoil 12 to 36 inches.	7463. ⅛ mile S. of NW. corner sec. 6, T. 151 N., R. 50 W., subsoil 4 to 6 feet.	7464. ⅛ mile E. of SW. corner sec. 22, T. 151 N., R. 50 W., alkali crust.	7465. ¼ mile S. of NW. corner sec. 10, T. 151 N., R. 50 W., alkali crust.	7466. West center sec. 31, T. 150 N., R. 55 W., subsoil 12 to 36 inches.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ions:							
Calcium (Ca)	6.74	5.83	16.82	13.31	1.76	7.34	24.56
Magnesium (Mg)	14.34	10.74	7.12	5.89	.81	14.24	1.55
Sodium (Na)	1.13	10.69	1.15	1.96	28.44	1.13	.94
Potassium (K)	1.42	.95	2.88	11.44	1.00	.59	1.55
Sulphuric acid (SO_4)	73.94	47.12	59.71	41.93	65.49	73.99	68.94
Chlorine (Cl)	.77	23.59	9.16	20.11	.64	1.56	.64
Bicarbonic acid (HCO_3)	1.66	1.08	3.16	5.36	1.86	1.15	1.82
Conventional combinations:							
Calcium sulphate ($CaSO_4$)	22.28	19.82	57.10	26.45	5.97	24.97	83.46
Magnesium sulphate ($MgSO_4$)	70.99	41.49	24.31	29.22	4.04	70.64	9.99
Sodium sulphate (Na_2SO_4)	2.55	......	......	......	85.91	......	2.35
Potassium chloride (KCl)	1.63	1.81	5.50	21.81	1.35	1.71	1.36
Sodium carbonate ($NaHCO_3$)	1.09	1.49	4.29	......	1.99	1.58	.72
Magnesium chloride ($MgCl_2$)	......	9.24	8.80	......	......	......	......
Sodium chloride (NaCl)	......	26.15	......	......	......	1.70	......
Calcium chloride ($CaCl_2$)	......	......	......	15.19	......	......	......
Per cent soluble	10.79	15.50	3.82	2.24	12.96	12.52	5.27

Part of the sodium, varying from 0.24 per cent in sample 7463 to 2.17 per cent in sample 7460, was probably in combination with organic acids, and is therefore not shown in the foregoing table.

AGRICULTURAL METHODS.

The principal products grown are wheat, oats, barley, flax, millet, and hay. Some vegetables are produced for the market, but not much importance is given to this branch of farming. The hay lands are confined chiefly to the low-lying and naturally swampy areas.

Wheat is by far the most important crop grown, and the product is very favorably known all over the country for its quality. The wheat is all spring sown and of the hard variety. In 1902 there was a greater area in the county devoted to wheat than to all other crops combined. In the same year flax was second in acreage, it having been grown much more generally that year than ever before. The increase that year was no doubt partly due to a desire to carry on more diversified farming, but also largely to the fact that the season was quite late and much of the land not dry enough in time to allow wheat or oats to mature. Millet was likewise grown more largely in 1902 than in any other year, which was also mainly due to a late spring. These two crops need less time to mature than do the cereals, and hence they are sometimes used as emergency crops.

Flax, however, is generally conceded to be an unprofitable crop to grow on the same piece of land for more than two successive years, owing to a peculiar disease known as "flax wilt." The trouble is due to a fungus which appears to be introduced with the seed. When affected the plants turn yellow and partly wilt, and are considerably stunted in growth. If by chance they mature—which a badly affected plant does not—the seed is smaller than the average flaxseed and of a very inferior quality. There seems to be no remedy yet discovered for the disease, and farmers are recommended by the experiment stations to take great care in selecting their seed and to treat it with formaldehyde. The crop is grown almost exclusively for the seed, nothing being as yet done with the fiber excepting a small amount used at Fargo for making hemp. Plans are being seriously considered, however, for putting in machinery at that place (the plant now is small) which would utilize more of the straw and make the industry more general.

There is but little systematic rotation of crops practiced. A number of instances were met with where farmers had planted wheat for eighteen or twenty years without any other crop as alternate, the only break in the scheme being two or three years of summer fallowing. The effect of such constant cropping is quite readily noticed in some parts of the area, though much of the land continues to yield apparently as good crops as ever. When land is considered in need of "rest" it is generally summer fallowed. A decidedly better plan would be to alternate with hoed crops of some kind, but

as the farms are generally extensive in area it does not seem to be considered worth while to expend the labor necessary to the production of such crops. More diversified farming could, however, be profitably introduced. Similarly little attention is paid to adaptation of crops to soils, any crop being planted on any kind of land.

Plowing is generally done in the fall, often before the grain is thrashed. This enables the seeding of the land to be done earlier in the spring than when plowing is left until spring, and this is an important matter on account of the shortness of the growing season. It is also a good practice in that it leaves the soil in a better condition for nourishing the next year's crop, as the weathering processes going on during the winter materially increase the available plant food. Especially is this true of the heavier soils.

The amount of seed sown to the acre varies widely, differing with the soil conditions and individual opinion. Any quantity from one and a quarter to three bushels of wheat per acre is sown, and adherents of both extremes claim the better results. Certain it is, however, that more seed is needed in late sowing than in early sowing, in order that too much stooling may be prevented and the crop forced to maturity as early as possible.

Grain harvesting is done altogether with the binder, and the thrashing is done by steam power. Usually the grain is not stacked, but is hauled direct from the shock to the thrasher. Considerable time, trouble, and expense are thus saved; but there is a slight loss attending this method, as wheat, especially, will usually sell a grade better if allowed to pass through the "sweating" process in the stack. It is generally considered, however, that the higher price received is not sufficient to warrant the trouble and expense of stacking.

The yields vary quite widely in different parts of the area, even on the same soil types, the variation depending on a number of factors. It is considered by unprejudiced observers that the average yield per acre is about twelve or fifteen bushels of wheat, and this is probably a low enough figure. Forty bushels per acre have been raised with favorable circumstances. Barley yields, on the average, from twenty-five to thirty bushels, and oats from thirty-five to forty bushels per acre. Flax, which is becoming an important crop, averages about fifteen bushels per acre. As before mentioned, this crop does better on land that has not been seeded to

flax for a number of years. An interesting case was met with in the area, where a piece of land had yielded twenty-five bushels per acre the first year—a big crop—twenty bushels the second, fifteen bushels the third, and about twelve to fifteen bushels the fourth year. This, however, was on a choice piece of land, and where good care had been given the crops.

Very little fruit has yet been raised or attempted to be raised in the county, the climate being too severe for any but the most hardy sorts.

AGRICULTURAL CONDITIONS.

The agricultural conditions of the state at large have improved greatly and in almost every respect during the last decade. In that time the cultivated area and the number of farms have increased nearly 100 per cent, the acreage per farm has increased from 277 to 343 acres, and the value of farm lands, improvements, buildings, live stock, etc., has almost doubled.

The number of acres in farms in Grand Forks county in 1900 was 861,872. There were 2,368 farms. The average size of farms was 364 acres, and the average value of each, exclusive of buildings and improvements, was $6,327. About 87 per cent of the farm land in the county is improved, and more is constantly being brought under cultivation. Generally speaking, the buildings and improvements are good, especially on the better lands, and the farmers are well supplied with the necessary live stock and implements for the successful operation of their farms.

The population of Grand Forks county is composed almost entirely of the farming class, and little interest is taken in stock raising except as an adjunct to the economical operation of the farm. The proportion of the farmers of Grand Forks county owning farms cannot be definitely stated, but for the whole state 91.5 per cent of the farms are operated by the owners and 7.2 per cent are operated by share tenants. This would probably be a very fair estimate of the conditions of tenure in the county. Some of the farms classed as operated by the owners, especially the larger farms, are in charge of managers appointed by the owners. The managers have general supervision of affairs and receive a fixed remuneration for their services. Quite often farms are operated by the owners and tenants in conjunction, the tenants receiving a share of the products.

Considerable labor is hired during the busy seasons of the year, and especially at harvest time. This being temporary employment, the laborer is paid considerably more than where the service is permanent, \$2.50 to \$3 per day for single hands being quite common, the work being shocking grain, assisting in thrashing, plowing, etc. Labor by the month or year is paid much less. According to a report of the county auditor, there were employed on the farms of the county, in 1901, 1,675 male and 347 female employees. According to the same authority, the average wages paid were \$24.25 and \$13 per month, respectively. There is very little colored help employed in the county.

The transportation facilities of the county are good. The main line of the Great Northern passes through the area from east to west, and a number of branches of this system radiate from Larimore and Grand Forks. The Northern Pacific system also touches the area, passing through Grand Forks.

Along the railroads, at frequent intervals and convenient points, there are small stations, each with from one to half a dozen elevators for storing products temporarily to await shipment. Few farmers have granaries of their own, but deliver their grain to the elevators immediately after it is thrashed, thus usually disposing of it at a lower price than could be obtained later in the year. But as the country is practically new and as many of the farmers have had to pay for their land in yearly payments, many of them are not yet in condition to hold their crop.

A prominent feature of the agriculture of the county is the operation of large farms. These frequently range between 1,000 and 5,000 acres, and in one—the largest in the county, and reported to be the largest grain farm in the world—11,000 acres were sown to crops in 1902. A movement is on foot, however, to have this place divided up into quarter sections and sold to colonists. This would introduce a more diversified farming, dairying, etc., and would be a good thing for the county. Some of the other owners of large farms are seriously considering doing the same thing, and better agricultural conditions will soon obtain if the plan is carried out.

SOIL SURVEY OF THE FARGO AREA.

By Thomas A. Caine.

Field Operations Bureau of Soils, 1903.

LOCATION AND BOUNDARIES OF THE AREA.

The Fargo area lies wholly within Cass county, one of the eastern tier of counties, and represents a typical section of the Red River valley from the Red River on the east to the highest shore line of glacial Lake Agassiz on the west.

It is confined within meridians ninety-six, fifty-one minutes, twenty-six seconds and ninety-seven degrees, thirty-two minutes, nine seconds west logitude and parallels forty-six degrees, forty-seven minutes, thirty-three seconds and forty-six degrees, fifty-seven minutes forty-seven seconds north latitude, and consists of townships 139 and 140, ranges 49 to 54 west, inclusive. There are 259,776 acres, or approximately 406 square miles, in the area.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The first white settlement in the Red River basin was as early as 1816, when the Selkirk colony, coming via Hudson Bay, settled in the vicinity of Winnipeg. From that time until about the middle of the century fur trading was the only occupation of the white settlers of the region.

In 1851 a few white settlers obtained some land from the Sioux Indians for agricultural purposes, but the Indians were so troublesome that these early attempts at agriculture were unsuccessful.

It was not until late in the seventies, after the Northern Pacific and Great Northern railways had penetrated the region, that the special adaptation of the soil for wheat became generally known. From 1875 to 1885 the settlement of the region was pushed forward very rapidly, nearly all of the land in the valley being taken up during these years by homestead or preemption claims from the government, or by purchase from railroad corporations of land which they had received from the government as grants. Agricultural development was very rapid along the main lines of these railroads, and branches were soon built which greatly increased the shipping facilities of the area and resulted in a great impetus to farming. Many settlers flocked in from the older states and many came from the Old World, especially from Norway, Sweden, and

Denmark. In 1889 Dakota territory was divided, and two states, North Dakota and South Dakota, were admitted to the Union. During the last decade land values in the area have nearly doubled, and the prospects are for still higher values. During the last few years more stock has been introduced into the country, and there is a strong tendency toward more diversified farming and better cultural methods.

CLIMATE.

Owing to the absence of timber lands and the geographic position of the area in the center of a large continent and at a high latitude, the difference between the temperature of summer and winter is very great. Usually there are only a few days in summer when the mercury gets as high as 100 degrees F., and the nights are always cool. The seasons are sharply defined. The growing season opens suddenly in April, when the surface of the ground thaws rapidly, permitting seeding in a few days. Winter is generally ushered in by a sudden cold wave in November, when the ground freezes and the fall plowing is stopped.

During the months of January and February the temperature is often from 10 degrees F. to 30 degrees F. below zero for days at a time, but owing to the dryness of the atmosphere this low temperature is not as difficult to endure as a much higher temperature along the coasts or lakes, where the humidity is usually greater.

The region may be classed as subhumid, the normal rainfall being about 23 inches. The following table, compiled from records of the Weather Bureau stations at Power and Wahpeton, N. Dak., and Moorhead, Minn. (across the river from Fargo, N. D.,) shows the normal monthly and annual temperature and precipitation:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Power		Wahpeton		Moorhead	
	Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches
January	11.4	0.50	9.0	0.34	0.9	0.73
February	7.0	.60	9.4	.59	4.5	.83
March	19.0	1.59	24.0	2.63	20.2	.87
April	41.0	1.88	46.0	2.45	41.3	2.23
May	54.0	1.99	58.0	2.99	53.2	2.50
June	65.0	3.73	66.0	4.27	64.8	4.36
July	69.0	3.80	70.0	4.12	67.6	3.91
August	67.0	1.79	68.0	2.83	65.2	2.68
September	60.0	1.16	61.0	1.44	56.5	2.09
October	45.0	1.35	46.0	1.35	43.1	1.92
November	23.0	.61	26.0	.60	24.2	.92
December	13.0	.82	16.0	.35	11.9	.72
Year	39.5	19.82	41.6	23.96	37.6	23.77

A study of the records of temperature year by year seems to indicate that the winters are less severe than formerly, the greatest change being in January and February. In those months there has been a decided increase in temperature, while in March, April and May the difference is less marked, and during the remainder of the year the conditions have been more constant. The milder winter is a fact well recognized by all farmers who have lived in the valley for a score or more of years.

Owing to the difficulty of getting onto the fields early enough in the spring to plow for seeding, nearly all of the plowing is done in the fall after harvest. This exposes the black soil characteristic of the valley to the sun during the winter months. The rainfall is greatest during June and July, the months when it is needed most by the growing crops. During January and February, the months in which there has been the greatest increase in temperature, the average precipitation is less than one inch. The small amount of snow that falls during these months is no longer lodged in the prairie grass as formerly, but is either blown off the plowed fields into the coulees or is melted upon the heat-absorbing black soil during the bright days. Before the country was broken up this snow was held in the prairie grass. A perfectly black body has the property of absorbing all radiations which fall upon it, and this increases its temperature. In the case of a black soil a part of the heat thus absorbed is again radiated, while a part of it is conducted away to other portions of the soil mass not exposed directly to radiation. The temperature of the soil, as a whole, is thus raised, and by radiation the soil warms the air to some extent. A perfectly re-

flecting body, on the other hand, which would in a way be approximated by the light-colored prairie grass and the white snow, would reflect all the radiation falling upon it without any corresponding rise in temperature. This may account for the change in winter temperature thought to have taken place in this region.

The term "killing frost" represents a frost which will kill such crops as are generally grown in the valley, and usually represents a temperature of 26 degrees F. If fruits or other more delicate crops were grown in the valley a higher temperature would have to be taken as indicating a killing frost. The average dates of killing frosts, based on records covering a period of twenty-two years, are as follows: Last in spring, May 14; first in fall, September 20.

PHYSIOGRAPHY AND GEOLOGY.

In preglacial times there was a broad, well-defined valley, cut through the soft, Cretaceous shale, sloping northward from the vicinity of what is now Lake Traverse, S. Dak., past Winnipeg, Manitoba, to Hudson Bay.

During Glacial times the bottom of this valley became covered to a considerable thickness with glacial debris or till, and when the ice sheet retreated northward it became filled with water from the melting ice, and a lake was formed, with its southern end near Lake Traverse, and extending northward into Canada. This lake is known as Lake Agassiz. The width varied, but when the water was at its highest level the average width was about 45 miles. The great ice barrier to the northward would not permit the water to flow in that direction, and the natural drainage during this period was southward over the lowest rim of the basin and through Big Stone Lake.

The melting ice furnished an abundance of water, and rapid glacial streams carrying rock fragments of all sorts and sizes, as well as finer materials, deposited them in the bottom of this great lake. The material carried in by the streams was sorted by the action of water, the heavy sand and gravel being dropped in the shallow water along the shore, there to be reworked by the waves and piled up by them into beaches, and the finer materials, silt and clay, being carried in suspension and deposited in the deeper water.

When the climate became warm enough to lower the ice dam below the level of the southern outlet of the lake, the water again

began flowing northward. The different beaches along the bottom of the old lake represent the different levels at which the water stood while the ice dam was being thawed away, and finally, when the ice was entirely removed, all but a portion, Lake Winnipeg, which was below the natural drainage channel, became dry.

The old lake bottom is now one of the most productive wheat-growing regions in the world, and is known as the Red River Valley, taking the name from the Red River of the North, which flows through it northward into Lake Winnipeg and thence through the Nelson River into Hudson Bay.

The Red River Valley is remarkably level, having a continuous, uniform slope northward of about 1 foot to the mile. The river itself flows along the lowest portion of the plain, and is very sluggish and meandering in its course. For the first 10 or 15 miles east and west from the stream the country rises imperceptibly, the average elevation being about 1 foot for every 5 miles.

The area surveyed comprises a typical section of the Red River Valley, extending from the Red River at Fargo westward beyond the highest shore line of the ancient lake. For the first 15 miles or so west at Fargo there are only about 3 feet difference in elevation. In the next 10 miles there is a gradual rise of about 8 feet to the mile. From Wheatland to the western edge of the area, a distance of 8 miles, there is a gradual rise of 22½ feet to the mile. From the Red River at Fargo westward to this point, a distance of 35 miles, there is a difference in elevation of 238 feet. Fargo has an altitude of 900 feet.

The highest shore line of the lake is represented by an abrupt beach which crosses the area at Magnolia in a northeast-southwest direction. The glacial till area to the westward is characterized by its rolling surface, made up of low hills, knolls, and kettle holes, and by the presence of rocks of all sizes strewn about the surface and disseminated through both soil and subsoil. This glacial till area passes under the lacustrine deposits to the eastward at a gentle angle. In several places in the western part of the lake area the knolls and hills of the underlying till come so close to the surface as to appear in the borings and along streams and in road cuts.

In places the distinct beach which passes through Wheatland appears to be made up largely of an escarpment of glacial till. At Casselton, 7 miles farther east, the underlying till is covered with the

lake deposit to a depth of 70 feet. At Fargo the till lies more than 100 feet below the surface deposit of lacustrine silt and clay.

While the surface of the lowest portion of the valley is practically flat, there have been some marked changes since the original deposition. For example, the Red River and its tributaries, the Sheyenne and Maple rivers, have cut channels into the silt and clay, and during freshets have overflowed, building up the lands immediately adjoining, which now are higher than the country a few miles away. This higher ground, both because of its looser texture and its better condition as to drainage, is more satisfactory for farming than the lower ground. The deep black soil characteristic of the middle portion of the valley doubtless results from peculiar conditions once obtaining in this lower lying area, which for many years after the recession of the lake was an extensive marsh.

The rocks from which the soils of the valley were originally derived can be seen in the lake beaches, and consist largely of granite, gneiss, limestone, and, to a small extent, of Cretaceous shale. But the latter rock has entered into the composition of the soil to a much greater extent than would appear from its relative proportion in the beaches, for it is very soft and much more easly ground to a flour by the glacier than the harder granite, gneiss, and limestone. Chemical analyses of the water from the underlying Cretaceous shale and a field analysis of a piece of pulverized shale taken from a well shows that it is quite alkaline. The fact that the alkaline rocks of the Cretaceous formation have entered largely into the composition of all the soils of the region accounts for the presence of alkali in all parts of the area.

SOILS.

Eight distinct types of soil were recognized and mapped in the Fargo area: The Marshall clay, Fargo clay, Miami black clay loam, Miami loam, Marshall gravelly loam, Marshall loam, Wheatland sand, and Wheatland sandy loam. The last-named type is unmodified glacial till; the other types are composed of the materials of this till sorted by water and more or less modified by weathering. The soils owe their distribution largely to the action of water, either of the glacial streams flowing into Lake Agassiz or of the lake itself. Thus, along the ancient shore is found a beach composed of coarse sand and gravel. Just east of this is found a sand classed

and mapped as Wheatland sand. Toward the middle of the lake occur the soils classified as loams, clay loams, and clays.

The regularity of the separation, sorting, and deposition of the glacial till material was more or less interfered with by the fact that as the ice sheet retreated to the north the lake stood at lower levels. These levels are represented by several parallel beaches.

The area of the several soil types is given in the following table:

AREAS OF DIFFERENT SOILS.

Soil	Acres	Per cent	Soil	Acres	Per cent
Marshall clay	76.800	29.6	Miami loam	11,968	4.6
Miami black clay loam	74 880	28.8	Marshall loam	7, 68	2.7
Fargo clay	40,000	15.4	Marshall gravelly loam	2,688	1.0
Wheatland sand	29,504	11.4	Total	259,776	....
Wheatland sandy loam	16,768	6 5			

MARSHALL CLAY.

The soil of the Marshall clay is a jet-black clay loam or clay from 18 inches to 2 feet deep. The subsoil is a grayish-brown silty clay or clay extending to a depth of 6 feet. From 6 to 9 feet the texture remains the same, but the color changes. When exposed to the air the subsoil breaks up into thin flakes resembling shale or slate.

This type occurs in large bodies in the eastern part of the area, principally between Maple River and Red River. The areas upon which it is found are a little higher than the Fargo clay or "gumbo" areas, but the differences in elevation are slight and the surface may be considered level. The condition of the Marshall clay has been greatly improved in recent years by the construction of ditches along the roads of every section line. The most desirable phase of this type is found along the rivers where the ground is a little higher and the drainage conditions are better. This type is purely a lacustrine deposit, but perhaps somewhat modified by the overflow of rivers subsequently to the time when it was laid down.

No injurious amounts of alkali were found in the first 3 feet of this soil, but the alkali increases in the lower depths and excessive amounts were often found in the sixth foot. Traces of bicarbonates and some sulphates were usually found in the surface foot.

The Marshall clay is recognized as one of the strongest soils of the area and as well adapted to wheat, oats, barley, flax, and corn. Because of its somewhat imperfect drainage it can not be seeded

as early in the spring as can the lighter types to the westward, and consequently the crops mature later on this soil.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MARSHALL CLAY

No.	Locality	Description	Organic matter per cent	Gravel, 2 to 1 mm per cent	Coarse sand, 1 to 0.5 mm per cent	Medium sand, 0.5 to 0.25 mm per cent	Fine sand, 0.25 to 0.1 mm per cent	Very fine sand, 0.1 to 0.05 mm per cent	Silt, 0.05 to 0.005 mm per cent	Clay, 0.005 to 0.0001 mm per cent
8451	NW. cor. sec. 24, Reed Tp.	Clay loam, 0 to 24 inches	5.31	Tr	4.04	6.50	11.80	11.50	39.28	27.10
8453	NE. cor. sec. 35, Barnes Tp.	Heavy clay loam, 0 to 24 inches	5.48	.06	.54	1.36	6.80	10.92	49.38	30.66
8455	Fargo	Black clay loam, 0 to 30 inches	5.7[illegible]	.74	7.78	7.74	10.56	7.48	33.80	31.94
8452	Subsoil of 8451	Brown clay, 24 to 40 inches	1.27	.00	.16	.2[illegible]	2.38	4.20	57.00	36.00
8456	Subsoil of 8455	Clay, 30 to 72 inches	Tr	.06	.10	.20	1.10	2.20	38.06	58.26
8454	Subsoil of 8453	Gray clay, 24 to 40 inches	Tr	.00	.30	.40	1.60	2.12	36.50	58.76

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8452, 7.77 per cent; No. 8455, 1.20 per cent; No. 8454, 18.8[illegible] per cent; No. 8456, 14.58 per cent

FARGO CLAY.

The Fargo clay consists of from 6 to 14 inches of heavy black clay, underlain by gray or blue clay of the same texture to a depth of 5 feet. From 5 to 9 feet it is composed of a mottled gray-brown and yellow clay identical with the corresponding section of Marshall clay. When wet this type is very waxy and gummy and has an oily feel. It is exceedingly slippery under foot and often sticks to the wagon wheels in such quantities that they present the appearance of mud disks. During the wet seasons it is a common sight to see great piles of this mud, or "gumbo" as it is called, along the roads, where the farmers have stopped to clean their wagon wheels. When dry this soil can not be turned by the plow, which either rides on the surface or pushes to one side or ahead of it cemented portions of the soil sometimes a yard across. When wet it is also difficult to cultivate, as it sticks to the plow.

The Fargo clay is found in all parts of the area from the Red River westward to Wheatland. It is not found west of this village, the soils there being lighter and the drainage more perfect. This

type is always found in depressions, and, owing to the impervious nature of both soil and subsoil, water often stands upon the surface for weeks after a copious rain. The largest areas of the type are to be found between the Red and the Maple rivers in the vicinity of Fargo and Haggart, but small patches of it may be seen almost everywhere associated with the heavier types of soil.

Alkali is always present in this soil, but usually not in injurious quantities. Except in a few isolated patches excessive amounts were not found in the first foot, but in the second and third feet the increase was usually quite marked. In nearly all cases the average for the first 3 feet was between 0.15 and 0.20 per cent. A few isolated spots, not large enough to be mapped on the scale used, were found where the average of the first 3 feet was as high as 0.40 per cent. If an average for the first 6 feet had been taken instead of the first 3 feet nearly all the areas would show a salt content of about 0.10 per cent. The greater abundance of salts in the Marshall clay is the result of accumulation by leaching from higher lying lands. The peculiar waxy, gummy characteristic of the soil, it is suggested, may be due to the presence of small amounts of bicarbonates. The experiments of the college farm at Fargo show that by surface drainage, deep plowing and turning under coarse manures these textural peculiarities can be considerably modified.

This soil is regarded as one of the strongest and most productive in the area when the season is favorable. The great difficulty is to get the seed in early enough in the spring and to keep the land from flooding and from baking after rains. Crops are often injured as much by the baking of the soil after a rain as by a flood. Under the present imperfect condition of drainage, it is only about one year in five that the season is such as to give the best crops from this type. As a result these lands are held in low esteem for general farming. When seeded with brome grass, or covered with natural prairie grass, they are excellent for hay and pasture.

The following table shows the texture of the soil and subsoil of this type as determined by mechanical analyses:

MECHANICAL ANALYSES OF FARGO CLAY

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8464	SE. cor. sec. 2, Gill Tp.	Clay, 0 to 12 inches	3.63	.20	1.30	1.10	4.00	9.50	37.82	46.00
8458	N. cen. sec. 5, Everest Tp.	Black clay, 0 to 12 inches	2.66	.12	.60	.80	3.40	6.70	34.48	53.90
8465	Subsoil of 8464	Clay, waxy when wet, 12 to 24 inches	1.58	Tr.	.70	.70	2.08	5.50	27.00	63.86
8459	Subsoil of 8458	Waxy, impervious clay, 12 to 24 inches	2.22	.00	.36	.46	1.08	4.10	25.02	68.98

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8458, 3.37 per cent; No. 8459, 2.59 per cent.

MIAMI BLACK CLAY LOAM.

The surface soil of the Miami black clay loam consists of about 14 inches of heavy gray or black loam, lighter in texture than the material of the Marshall clay. This is underlain by a silty clay loam to a depth of 36 inches, beneath which occurs a chalk-colored material, slightly coarser in texture, and reaching to a depth of 6 feet. In the lower depths this light-colored material becomes yellowish owing to the presence of iron oxide. Small beds of gypsum often occur in the second foot.

This soil type is found in a large, continuous body which extends across the area in a northeast-southwest direction from the vicinity of Maple River westward nearly to Wheatland. From the extreme eastern limit to the extreme western limit of the type there is a difference in elevation of nearly 60 feet. This gives a gradual rise of about 6 feet to the mile, so that the drainage conditions are more favorable than in any of the types to the eastward. Because of this and of the more porous nature of the subsoil, water seldom stands upon the surface long enough to cause injury to growing crops or to retard cultivation. This soil retains moisture well and gives it up in time of drought when the growing crops most need it. The soil is typically developed in the regions north and south of Casselton.

To a depth of 3 feet there are no injurious amounts of alkali in either soil or subsoil. Below that depth the amount sometimes becomes considerable. A trace of black alkali was found in the surface foot.

The Miami black clay loam is the soil which has contributed most to the fame of the Red River Valley as a wheat-growing district. As developed in this area, it seems especially well adapted to this crop, although in the Central West it is considered a typical corn soil, much less desirable for wheat than some of the prairie types. The rigorous climate of the Red River Valley is less suited to the production of corn than of wheat, and this fact has tended to limit the use of the Miami black clay loam to wheat production.

The extensive development of the Miami black clay loam in the valley, its generally smooth surface and good drainage, all favor the most extensive methods of farming, and there are probably no wheat farms in the world larger than those found in the Red River Valley.

The production of corn on this type is increasing, and it is thought that ultimately an early-ripening variety will be established and the risk of damage from freezing reduced to such a degree that corn will form an important crop of the area. Large yields of Irish potatoes can be produced on this type, but this crop is at present grown only for home consumption.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm.—per cent	Coarse sand 1 to 0.5 mm.—per cent	Medium sand, 0.5 to 0.25 mm.—per cent	Fine sand, 0.25 to 0.1 mm.—per cent	Very fine sand, 0.1 to 0.05 mm.—per cent	Silt, 0.05 to 0.005 mm.—per cent	Clay, 0.005 to 0.0001 mm.—per cent
S. cen. sec. 35, Casselton Tp.	Brown loam, 0 to 14 inches	4.03	0.14	0.40	0.70	2.44	13.86	67.76	14.68
Sec. 1, Harmony Tp.	Brown loose loam, 0 to 20 inches	4.69	.00	.90	.52	4.20	40.56	36.58	17.20
Sec. 34, Everest Tp.	Brown loam, 0 to 15 inches	3.39	.30	.88	.78	1.88	30.90	34.54	30.54
Subsoil of 8422	Gray loam, 20 to 36 inches	4.81	.00	.40	.50	1.78	34.60	39.26	23.30
Subsoil of 8298	Gray clay loam, 14 to 36 inches	Tr.	.18	.16	.24	.86	7.92	64.50	25.80
Subsoil of 8425	Loam, 15 to 36 inches	Tr.	Tr.	.62	.46	1.36	21.86	42.56	32.90

llowing samples contained more than one half per cent of calcium carbonate ($CaCO_3$): 3.53 per cent; No. 8299, 18.63 per cent; No. 8423, 8.01 per cent; No. 8426, 20.15 per cent.

MIAMI LOAM.

Miami loam is composed of about 20 inches of heavy, rich own loam, somewhat similar in texture to the surface material

of the Miami black clay loam, grading without a perceptible change of texture into a grayish-yellow clay loam or clay. Below the third foot the soil retains the yellowish color, and sometimes becomes a trifle sandy. Iron oxides are often present in the lower depths and crystalline gypsum is frequently found in the second and third foot.

This type includes an area from 1½ to 2 miles wide, extending in a northeast-southwest direction along the eastern border of the distinct beach which passes through Wheatland. It is bordered on the east by the Miami black clay loam. The area covered by this type slopes gently toward the east, the inclination being sufficient to insure good drainage. This fact, together with the richness of the soil and its somewhat porous nature, makes it one of the most desirable types in the Red River Valley. It can be seeded or planted irrespective of wet weather, and the porous nature of the soil allows the moisture below to rise by capillarity in times of drought.

With the exception of a few spots, this type carries less than the minimum, 0.20 per cent, of alkali in the first 3 feet. The alkali content increases in the lower depths, but is not high enough to injure plants in any of the first 6 feet. The few spots where the injurious salts are found in excess are close to the sand beach forming the western boundary of the type, and seem to be due to saline springs which ooze out of the sand and gravel. With the exception of a narrow strip in secs. 3 and 10, Gill township, these areas were not large enough to be shown on a map of the scale used. They usually range from a few square rods to 2 acres in extent.

The typical areas of the soil are well adapted to wheat, oats, barley, corn, millet, and flax. During dry seasons the crops suffer to some extent from the effects of alkali.

The following table shows the texture of the soil and subsoil of this type:

MECHANICAL ANALYSES OF MIAMI LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8434	S. cen. sec. 6, Casselton Tp.	Brown loam, 0 to 14 inches	6.75	3.50	7.84	4.74	18.76	25.86	26.60	12.66
8436	S. cen. sec. 13, Wheatland Tp	Brown loam, 0 to 15 inches	6.35	.00	2.80	5.50	21.00	19.96	29.92	20.86
8438	Middle of sec. 15, Gill Tp	Brown loam, 0 to 20 inches	5.56	Tr.	1.44	2.00	15.10	24.70	35.78	20.92
8435	Subsoil of 8434	Brown clay loam, 14 to 36 inches	1.42	7.50	9.18	4.38	13.68	18.68	22.20	24.06
8437	Subsoil of 8436	Clay loam, 15 to 36 inches	Tr.	1.00	2.80	2.60	9.30	9.40	25.48	48.80
8439	Subsoil of 8438	Yellow clay, 20 to 36 inches	.83	.00	.71	.72	5.18	12.48	25.90	54.76

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8435, 14.57 per cent; No. 8437, 8.81 per cent; No. 8439, 9.02 per cent.

MARSHALL GRAVELLY LOAM.

The Marshall gravelly loam is composed of about 12 inches of heavy black sandy loam, underlain by 2 feet of coarse gravel resting on a coarse sand extending to a depth of 6 feet or more. The most abundant rock constituent of the gravel is limestone. There are also present considerable quantities of granite and other crystalline rock fragments, and a few fragments of Cretaceous shale.

The type represents beaches formed during the recession of glacial Lake Agassiz. These beaches cross the area in fairly well defined lines in a northeast-southwest direction. In places they are broken down or obliterated, while in other places they appear like escarpments of glacial till modified by the action of water. In some places there are considerable quantities of large glacial bowlders strewn over the surface, but these are not numerous enough to seriously interfere with cultivation, and in most areas they have been gathered into piles. Where the railroads cut these beaches, large quantities of sand and gravel have been taken out for use along the tracks. The materials are also used throughout the country for building purposes.

Except in very wet seasons the crop yields on this type are very light, owing to the excessive drainage resulting from the gravelly nature of the subsoil. The areas occupied by this type are narrow, usually no more than 60 rods wide.

The following table gives the mechanical analyses of typical samples of fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL GRAVELLY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8446	SW. cor. sec. 6, Casselton Tp.	Brown, heavy, sandy loam, 0 to 14 inches	6.87	4.50	14.22	12.72	18.22	17.60	20.52	11.28
8449	N. cen. sec. 3, Gill Tp.	Brown, sandy loam, 0 to 14 inches	5.65	5.50	13.34	9.04	15.26	9.86	27.16	19.76
8447	Subsoil of 8446	Coarse gravel, 14 to 36 inches	.43	12.16	28.56	27.76	24.46	1.76	1.96	3.12
8450	Subsoil of 8449	Coarse gravel and sand, 14 to 36 inches	.74	6.00	16.46	13.76	48.66	4.98	4.70	5 34

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8447, 4.18 per cent; No. 8450, 5,14 per cent.

MARSHALL LOAM.

The soil of the Marshall loam consists of a dark-colored loam which grades into grayish-brown loam at about 8 inches below the surface. This is underlain by a gray silt or clay loam or clay containing some grit and reaching to a depth of 4 feet. Below the fourth foot the texture remains the same, but the color changes from grayish to yellowish. Below the second foot the materials are very similar to those occupying the corresponding section of Miami black clay loam.

This soil occupies the plateau area, extending in a northeast-southwest direction, in a body about 2 miles wide, across Wheatland and Gill township. It is bounded on the east by an ancient beach and on the west by the gently rising area occupied by the sandier type of soil, the Wheatland sand. Some of it is in a slight depression, but the porosity of the subsoil and the good natural drainage make it desirable for all farm crops. It is a little more subject to drought than the Miami loam. The chief distinctions between the Marshall loam and the Miami loam are that the latter has a deeper soil and is not so subject to drought. The crops yield a little better also, and altogether the Miami loam is recognized as the more desirable type. Along the western edge of the Marshall loam

area, where it comes in contact with the Wheatland sand, there are several patches of ground, usually not more than a few square rods or at most a few acres in extent, upon which oats, wheat, corn, flax, and other crops, after germinating and beginning an apparently healthy growth, are soon dwarfed and killed, while the closely adjoining crops present a healthy and vigorous appearance and on maturing give a satisfactory harvest. These spots are usually moist, and in dry weather a considerable crust of alkali can be seen. They are in the lower places, and where the underlying glacial till is only a short distance below the surface and are caused by the rise of the alkaline waters from the glacial till and the accumulation of the salts on the surface by evaporation. A field analysis of the soils in these spots shows that the chlorides predominate, but that considerable quantities of sulphates and some bicarbonates are also present.

This soil owes its origin partly to the transportation of fine sand from the higher lying Wheatland sand to the westward and partly to the overwash of the beach to the eastward during recession of the glacial lake. A little crystalline gypsum is found in some of the areas, usually not far beneath the surface, while at lower depths iron oxides are usually present.

The Marshall loam is recognized as a good, safe soil, regardless of wet or dry seasons. It is a better soil for all farm crops than any type in the area farther west, but the yields are not quite as large as on such types as the Miami loam and the Miami black clay loam, which have heavier subsoils. On the other hand, it is more easily worked. It is well adapted to wheat, oats, barley, corn, flax, Irish potatoes and truck crops.

The following table gives the mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MARSHALL LOAM

No.	Locality	Description	Organic matter per cent	Gravel, 2 to 1 mm per cent	Coarse sand, 1 to 0.5 mm per cent	Medium sand, 0.5 to 0.25 mm per cent	Fine sand, 0.25 to 0.1 mm per cent	Very fine sand, 0.1 to 0.05 mm per cent	Silt, 0.05 to 0.005 mm per cent	Clay, 0.005 to 0.0001 mm—per cent
8428	[illegible] sec. 4, [illegible]	Brown [illegible] 0 [illegible] inches	4.7[illegible]	[illegible]	1.7[illegible]	2.64	11.21	26.96	29.17	17.58
8432	[illegible] sec. 17, [illegible]	Brown [illegible] 0 [illegible] 24 [illegible]	[illegible]	[illegible]	[illegible]	.60	12.20	22.22	41.04	15.25
8430	N. [illegible] sec. 34, [illegible] land Tp.	Heavy [illegible] 18 [illegible]	7.1[illegible]	.90	3.7[illegible]	4.30	13.94	16.70	27.60	22.95
8433	Subsoil of 8432	[illegible] 24 [illegible]	[illegible] 14	.8[illegible]	2.26	2.70	9.60	16.20	35.0[illegible]	33.06
8429	Subsoil of 8428	[illegible]	1.18	[illegible]	.8[illegible]	.84	7.0[illegible]	21.7[illegible]	36.32	34.[illegible]0
8431	Subsoil of 843[illegible]	[illegible] 18 [illegible]	1.11	1.01	.82	1.9[illegible]	4.90	6.96	42.7[illegible]	40.60

[illegible] CaCO₃ [illegible] No. 8429, [illegible] per cent; No. [illegible] 1 [illegible] per cent; No. [illegible] 21 [illegible] per cent; No. [illegible] per cent.

WHEATLAND SAND.

The Wheatland sand is [illegible] from twelve to eighteen inches of a [illegible] sand, which is underlain by grayish-[illegible] sand [illegible] of the same texture to a depth of three feet. Below this [illegible] and yellower. At about six feet the material [illegible] of grayish-yellow color, [illegible]. The underlying [illegible]

[illegible] miles wide, extending [illegible] through [illegible] the west [illegible] Glacial Lake Agassiz [illegible] the Marshall loams. [illegible] is a rise of [illegible] narrow strips [illegible] and 14 in [illegible]

The Wheatland sand was formed by wave action, in shallow water, during the recession of the ancient lake. Throughout the type are several low beaches, often only a few feet high, and upon the crests of these beaches the soil is usually too loose and sandy to be of value under the present conditions of agriculture. This type is the lightest soil in the Fargo area and needs much rain to insure fairly good crops. The crops are sometimes blown out by strong winds.

With the exception of some limited areas along the eastern border of this soil, it is freer from alkali than any of the other soils. The limited areas already mentioned are closely associated with the alkali spots referred to in the description of the Marshall loam, and are confined to the lowest portions of sections 28, 32 and 33, Wheatland township. A field analysis of soil from these spots showed that they contain injurious quantities of both bicarbonates and chlorides.

In growing wheat this soil usually produces a good growth of straw, but the plants do not head well and the yield is light. It is well adapted to pasture and grazing.

The following table shows the texture of typical samples of fine earth of this soil:

MECHANICAL ANALYSES OF WHEATLAND SAND

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm per cent	Coarse sand, 1 to 0.5 mm per cent	Medium sand, 0.5 to 0.25 mm per cent	Fine sand, 0.25 to 0.1 mm per cent	Very fine sand, 0.1 to 0.05 mm per cent	Silt, 0.05 to 0.005 mm per cent	Clay, 0.005 to 0.0001 mm per cent
8476	Sec. 17, Wheatland Tp.	Brown sandy loam, 0 to 18 inches	2.27	0.90	3.48	5.50	47.20	23.58	12.08	7.46
8478	Sec. 24, Howes Tp.	Sandy loam, 0 to 18 inches	2.55	.86	3.68	5.36	49.58	21.98	11.52	7.46
8477	Subsoil of 8476	Gravelly loam, 18 to 40 inches	.92	17.20	19.30	5.18	29.90	13.50	12.78	11.04
8479	Sub-soil of 8478	Gravelly loam, 18 to 40 inches	1.50	12.90	9.56	5.46	23.38	15.48	12.00	11.06

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8477, 10.30 per cent; No. 8479, 7.93 per cent.

WHEATLAND SANDY LOAM.

The Wheatland sandy loam is composed of about fourteen inches of dark-brown sandy loam, underlain by a loam which at a depth of six feet or more rests upon a grayish-yellow or yellow glacial till.

Throughout the subsoil occur small rock fragments, varying from the size of a pea to that of an egg. In the second and third feet gypsum often occurs, and in lower depths concretions of iron oxide are usually present. Often the surface is strewn with gravel, especially on the crests of the prairie swells. Glacial bowlders of limestone, granite, gneiss and schist are abundant in places, though not usually in sufficient quantities to interfere with cultivation.

This type is found in the extreme western part of the area outside the limits of the territory once covered by Lake Agassiz. It extends westward past Buffalo, where the surface becomes more undulating. There is a gradual rise of about twenty feet to the mile toward the west, and the drainage is better than elsewhere in the area. In places there are many swales and kettle holes, with knolls and hills rising above them. Some of these places are filled with water the year round; others have a thick deposit of muck. None, however, were large enough to be shown in a map of the scale used, most of them being only an acre or two in extent.

No injurious amounts of alkali were found in either soil or subsoil to a depth of three feet, but several six-foot and nine-foot borings were made, and in these lower depths the alkali is sometimes found in considerable quantities. A few low spots contain so much alkali that nothing will grow, but these spots are usually not more than one or two rods across.

When the dry season is not too long the Wheatland sandy loam is a fairly desirable soil for general farming, as both soil and subsoil are of such a texture as to retain moisture well and to supply it to growing crops in time of drought. The soil varies according to location. On the crests of the prairie swells it is somewhat more sandy and gravelly than in the depressions, where the texture is decidedly more loamy. The soil in the lower places is regarded as more desirable when the season is not too wet.

This type is made up wholly of glacial till and is esteemed a stronger and safer soil than the Wheatland sand. But, like the latter, considerable of it is still unbroken and is used only for the production of wild hay and as pasture. This type produces fair crops of wheat, oats, flax, barley and corn. In the more loamy places it is found to be remarkably well adapted to Irish potatoes and other root crops.

ıe following table shows the texture of the fine earth of soil and ɔil as determined by mechanical analysis:

MECHANICAL ANALYSES OF WHEATLAND SANDY LOAM

Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
E. cor. sec. 10, Buffalo Tp.	Brown sandy loam, 0 to 15 inches	6.31	2.50	4.40	4.10	17.52	19.46	35.16	16.96
E. cor. sec. 21, Howes Tp.	Brown sandy loam, 0 to 14 inches	6.98	1.50	4.46	4.94	19.00	20.74	28.88	20.4
E. cor. sec. 34, Buffalo Tp.	Brown sandy loam, 0 to 12 inches	4.87	1.20	4.16	4.66	6.50	20.38	30.70	22.00
ıbsoil of 8440	Yellow sandy loam, 15 to 36 inches	1.02	2.08	4.54	4.02	16.94	20.66	32.14	19.30
ıbsoil of 8444	Yellow loam, 14 to 36 inches	Tr.	2.24	5.10	5.76	20.28	19.18	19.78	27.00
ıbsoil of 8442	Yellow loam, 12 to 40 inches	1.54	2.50	6.10	5.30	15.98	18.68	22.50	28.40

following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): 40, 2.17 per cent; No. 8441, 15.53 per cent; No. 8442, 4.35 per cent; No. 8443, 23.54 per cent 44, 7.11 per cent; No. 8445, 22.68 per cent.

DRAINAGE.

ıe most important problem in the Red River valley and the one ·hich the farmers are taking the keenest interest, is the problem rainage. Westward from the Red River to the Maple River, in stance of fifteen miles there is only a difference of three feet in ation. There are approximately 25,000 acres of land in this upon which the water from the melting snow often does not off or soak into the ground soon enough to permit seeding at proper time in the spring. The subsoil is heavy, gummy, and ːrvious to water. This, together with the fact that the frost is from five to eight feet below the surface, would make un- lrainage very difficult, if not impossible. Some farmers "mud their crops; others are not able to do even this, the land being oft that it is unsafe to put teams on it. "Mudding in" crops is · unsatisfactory, because after it is done the ground bakes so l that a great deal of the seed never comes up, or is "choked off" r it does come up.

ı seeding time after a copius rain all farm operations have to be poned from a week to ten days, while the water gradually soaks

into the ground or slowly drains off. The seriousness of all this is more fully realized when one takes into account the shortness of the growing season in North Dakota, and also when one sees the disastrous effects of standing water upon growing crops. In the area under discussion, under the present imperfect conditions of drainage, it is only about one year in five that paying crops are harvested. It should be kept in mind that these wet areas, indicated on the soil map as the Fargo clay, are not altogether unproductive, but under favorable conditions produce the largest yields of grain of any soil type in the Red River valley. But the uncertainty of yield has led to the abandonment of these lands by most of the original owners, and at present it is often impossible even to find tenants willing to cultivate them. The few houses in this region are tumbling down, the yards are growing up to weeds, and the general appearance of things is in marked contrast with the prosperous appearance of the farms on the adjacent higher lying and better drained areas, indicated on the soil map as the Marshall clay. An unfortunate feature is that these lands are upon the market for speculative purposes and are quoted as high as the best lands adjoining. The unacquainted buyer who comes into the country with an honest intention of making it his home is often deceived, being led to believe that all Red River valley land is the same.

There are several causes for the present unfavorable condition of drainage in the Red River valley, the principal ones being the levelness of the country and the lack of fall in the Red River itself. It should be kept in mind, too, that the river flows north, and consequently the difference in time when the ice breaks up in its lower and its upper courses tends to hold the water back. Another thing which checks the flow of the stream is the crookedness of its channel. As a result, the river rises, backs up its tributaries and frequently the latter overflow their banks and flood the fields.

Obviously, man can not regulate the periods at which the ice breaks up in the lower and upper courses of the Red River, nor would it be practicable to attempt to deepen the channel; but enough remains to be done to greatly improve the present conditions, and the fertility and importance of the region to be benefited warrants the expenditure of a large sum of money. For example, where the channel is so crooked and meandering as to retard the river's flow,

could be straightened so as to give the water a free course. Another important move in the control of the river, and one which has een under consideration for some time, is the construction of a orage reservoir in its upper course. During the spring freshets, d until after the ice had broken up along the international boundy line and beyond, this could be used to retain the water, which ould then be let off gradually.

The most practical scheme, however, and the one which would be of nmediate and probably of permanent relief, would be the construcion of deep canals from the rivers to the undrained areas. In this natter the consideration of most vital importance is whether the fall between the undrained areas and the rivers is sufficient to carry off the water in case canals are constructed. From observations made during the survey and from an examination of the records of previous years' floods the conclusion is that such a scheme is entirely feasible. The main reason why drainage by this means has not been successfully established in the past is that it is too big an undertaking for private persons and needs state or national aid.

The record of the stages of the Red River at Fargo show that during the month of April the mean height of the river is approximately thirty feet below the level of the prairie. The undrained areas are from two to four miles west of the river, so that this would give a fall of from seven to ten feet per mile. It is believed that this is sufficient provided the canal were about twenty-five feet wide and fifteen feet deep. In this connection it might be well to state that the water table in this part of the Red River valley is about twenty-two feet below the surface, so that there is no danger of encountering it in a fifteen foot canal. Along the Sheyenne river, in the vicinity of Haggart, the conditions at first sight do not seem so favorable, because the mean height of the river during the month of April is only about eight feet below the level of the prairie, but as the undrained area east and west of the river is only from 1 to 2 miles off, this gives nearly as great an average fall per mile as in the area near the Red River. A canal dug from the Sheyenne at Haggart directly west for three miles to the large coulee would not only drain the wet area directly west of the river, but by deepening the coulee which goes southwest into Durbin township the large wet area in the vicinity of Durbin would also be drained.

The chief purpose of these canals would not be to carry off the water of spring freshets, but to furnish a ready outlet for the water which accumulates in these low places after heavy rains. In the higher lying areas, indicated on the soil map as the Fargo clay, there is a road along every section line and a ditch on each side of the roads. After a heavy rain the water of these areas finds a ready outlet through the ditches, and often this water accumulates in the lower areas, converting them into sheets of water and drowning out the crops. By the construction of canals the waters of the higher areas would be afforded a direct course to the rivers. Then by the construction of roads and ditches along all the section lines of the low, wet areas the rain water would have a free course through the ditches and canals into the rivers also. It has been demonstrated by the experiments on the college farm at Fargo that the first requisite in reclaiming the low, wet lands is drainage, and that then by deep plowing and careful methods of cultivation the "gumbo" properties of this soil gradually disappear.

ALKALI IN SOILS.

All the soils of the area contain some alkali either in the soil, the subsoil, or in still lower depths. The "gumbo" areas and an area of low, sandy country west of Wheatland, occupied by the Wheatland sand and the Marshall loam, are the only areas which contain injurious amounts of alkali in the first three feet.

It was found that in the "gumbo" or Fargo clay areas the surface foot was comparatively free from alkali, while in the sandy area, referred to above, the injurious alkali was either upon or near the surface. This was found to be due to the fact that in the case of "gumbo" there is no percolation upward of soil moisture because the soil is too impervious, and hence there could be no concentration near the surface by evaporation. In dry weather the surface of the heavy soil bakes and cracks up into irregular pieces. In the case of the sandy area the water table is only from six to fifteen feet below the surface; sufficiently near for capillary forces to bring the underground water to the surface. The worst alkali conditions were found where the water table was nearest the surface and where the soil was also sandy and porous. Wells in this vicinity are commonly so alkaline that the water can not be used for drinking purposes.

Fair crops were seen growing upon the Fargo clay when the average for the first three feet was as high as .35 per cent alkali, but with the greater amounts in the second and third feet, while in the sandy area west of Wheatland the grain was killed when the average for the first three feet was only .20 per cent alkali, but with a concentration in the first two or three inches.

Injury from alkali is very largely a matter of seasons. If it happens to be wet at seeding time and continues so until the crops get a good start there is apparently no injury. On the same piece of ground the crops may be entirely killed the next year if the soil is very dry at seeding time and the alkali is concentrated near the surface.

In the case of the Marshall clay the alkali content gradually increased downward to six feet, with apparently no concentration in any particular foot section, while in the case of the sandy soils west of Wheatland the alkali content decreased until there was often almost none at nine feet. No borings were made deeper than nine feet. In the higher lying areas of the Wheatland sand, where the water table was far below the surface, the soil was often free from alkali, and only a very little was found in the lower depths of the subsoil. In all other types in the area the alkali content invariably increased in the deeper subsoil.

There seems to be no relation between the proportion of alkali in the soils and in the water of wells, except when the soils are very porous, as in the case of Wheatland sand, and the water table is only a few feet below the surface.

Along the foot of the old beach which passes through Wheatland there are several small spots which are so badly alkaline that the crops usually "burn out." Only one of these spots was large enough to map on the scale used. These spots are the result of the seepage

Under the present methods of farming, where land is so plentiful and where everything is done on such a large scale, the alkali will never be a serious problem. Nothing has ever been done to remove
from alkali springs at the bottom of the old beach.
it, and very little is said or thought about it. The all-important question over most of the area, and the question which is being seriously considered, is how to drain the low, flat lands in the vicinity of the Sheyenne and Red rivers.

AGRICULTURAL METHODS.

The early settlers of the Red River Valley were surrounded by conditions very different from those in almost any other part of the country. There were no rocks to be removed and no forests to be cleared. The settler had simply to build his sod house and barn, turn up the rich, level prairie soil, and sow his seed.

When the special adaptation of the valley for wheat became known the region leaped into prosperity, and the land values—a few dollars an acre a generation ago—have steadily increased to an average of $35 an acre at the present time. No other portion of the country could compete in wheat production with this region, because of the cheapness with which this crop could be produced and the vast scale upon which it was grown. The gradual extension of the wheat-growing region to other portions of the northwest and the lower Canadian provinces has made the supply greater and the prices lower. The continual growing of wheat for twenty years has in most places decreased the yield from the soil about one-half. These conditions are forcing the farmers of the region to adopt better methods.

Since its introduction flax has been one of the most profitable crops in the area, and especially so upon new land. It has been so profitable that farmers have been known to pay for their farms with profits from two crops. During the past few years, however, the crop has been seriously affected by a fungous disease popularly known as "flax wilt." The disease has been studied at the experiment station at Fargo, and the experiments, together with a study of the conditions in other flax-growing countries, show that the plant can not be profitably produced year after year upon the same land.

The spread of the disease to new lands can be avoided by the selection of healthy seed and by the treatment of all seed with a solution of formaldehyde. As yet no method has been found to do away with the fungi after the soil has been infected. In Russia and Belgium, where the plant is extensively grown, a period of from seven to twelve years is necessary between the crops if this disease is to be avoided. Crops in closer succession become wholly worthless on account of the disease.

A considerable revenue is now obtained from the sale of flax straw, where formerly it was burned after threshing. The farmers haul the straw to the mill at Amenia, or at Fargo, where it brings

$2 a ton. It is drawn to market in the winter when the roads are hard and at a time when farmers have little else to do. The mills dispose of their product in the east, where it is used largely in the manufacture of paper.

During the last two or three years macaroni wheat has been grown to some extent; and, although the price is lower than that for the standard varieties grown in the area, the fact that the yield is about one-third larger is making the variety popular.

On the loamy types of soil where the drainage conditions are favorable Irish potatoes do remarkably well, sometimes yielding as high as 200 bushels per acre. As yet they are grown only to supply local markets, though a few shipments have been made to southern states for use as seed.

The climate and soil is well fitted to the production of nearly all kinds of late vegetables. Celery does very well, and, judging from a few sugar beets grown in gardens, it would seem that there is a good opportunity for the introduction of that industry.

Strawberries, gooseberries, raspberries, and currants, provided they are sheltered from the winds by hedges of golden Russian willow, Norway spruce, soft maple, poplar, or in fact any kind of tree that will endure the climate, can be profitably produced. There is no one thing which is needed more or which would be of more value to the area than trees. Along the Sheyenne river in the vicinity of Haggart, where there are many large native trees, the weather in winter is much milder. In the midst of these trees a few apples and plums are being successfully grown, largely because the young trees are protected from the cold winds and the blossoms are not blown off in the spring.

Corn has been introduced and acclimated to the short growing season, and is now one of the important crops of the area. It is usually rotated with wheat, the latter producing greater yields and being freer from weeds if sown after the cultivated crop of corn.

Throughout the area there is a general lack of care in plowing and in preparing the seed bed. Plowing is usually very shallow, and this has decreased the productiveness of the soil. The practice of plowing a little deeper every third or fourth year and bring up an inch or so of the new soil to the surface to be acted upon by the weather and soil bacteria, is the most satisfactory method. It is best to plow in the fall and harrow immediately, so as to fill up the large air spaces and prevent the furrow splice from drying out. If

this is done, the soil will settle down sufficiently during the winter and spring months to establish good capillary connection with the subsoil.

No commercial fertilizer has ever been used in the area, and heretofore the opinion has prevailed that barnyard manure was more injurious than beneficial to crops. Where coarse manures are turned under they often have a tendency to make the soil too dry. When well-rotted manures were turned under they often had a tendency to make the growth of straw so large that it would lodge before harvesting. During the last few years, however, it is found that crops are greatly benefited if well-rotted manure is spread on the plowed ground in the fall and allowed to remain there all winter. It is often advisable to rake up and burn the coarse litter in the spring at seeding time. A great deal of manure in the area is still wasted, as formerly, by being dumped into the sloughs or drawn out in piles and burned.

AGRICULTURAL CONDITIONS.

The chief resources of the area are found in its very productive soil, especially as adapted to the production of grain. On the better types of soil and where the farmers have paid attention to business most of them have become independently wealthy. In most cases they came into the country when it was new and either acquired their lands from the government as homesteads or purchased them cheaply from other settlers who had thus obtained them. A large part of their present wealth, therefore, has not been made off the land itself, but on the natural increase of land values, which have [illegible] from a few dollars to about $35 an acre at the present, [illegible] of still higher value in the future.

A [illegible] persons who spend no part [illegible] their property in the hands [illegible] for cash or on shares [illegible]

[illegible] acres, although a few [illegible] were generally ac- [illegible] the odd numbered [illegible] as a subsidy to [illegible] a compact tract the [illegible] settlers, so that at [illegible] acres. The

two largest holdings in the county are one at Casselton, containing 13,000 acres and another at Amenia, containing 20,000 acres. The former is operated as a single farm, while the latter is owned by a company and leased on shares to tenants, no single tenant being permitted to work more than one section. In the vicinity of Fargo and Casselton the farms are larger than around Wheatland, and the average size of the farms throughout this area is about 600 acres.

As a rule the present land values of the area are on a legitimate basis. In a few localities where the drainage is very imperfect the land values are a little higher than the present conditions would seem to warrant, but on the whole there is bound to be a healthy increase upon the present basis. Some of the best farms are mortgaged, but these mortgages are held by local investors. In this portion of the northwest farm mortgages indicate prosperity rather than adversity. The farms that a score or more years ago were too large for the poor farmer with his large family of small children are now too small for the grown-up boys. The family spreads and the boys marry and buy adjoining farms. The father gives them a start with a few hundred dollars, to which they add their own savings. A part is paid down for the farm and a mortgage is given for the remainder and in the majority of cases with care and industry it is only a few years before the boys have clear titles to their farms.

The question of labor is one that is continually causing dissatisfaction among those who are operating large farms. One reason is that the poor man of enterprise and push will not remain a day laborer long because of the opportunity of his getting land and starting a home of his own. Men with enough money to make a small payment and sufficient stock and machinery to start work have been known to pay for a half section of land in two years. At the present time men of no money or stock and machinery, but with a reputation for honesty and industry, usually have no trouble in obtaining a farm with buildings, stock and machinery, and are given plenty of time in which to pay for them. The usual method is by "crop payments," giving one-half the crop each year until the indebtedness is canceled. Upon such terms with ordinary seasons and industry a man with one or two boys old enough to work can get clear title to a half section in less than ten years, provided the farm is located upon such types as the Miami black clay loam or the Miami

loam. By a process of natural selection these conditions have brought as laborers a class of unmarried men who are usually rather undesirable. In the winter they divide their time between the great cities and the lumber camps of the middle west; in seeding and harvest time they migrate to the grain-growing communities and demand exorbitant wages. The farmer who has to hire is at their mercy and must pay at least $2.50 a day for common labor, besides furnishing board and lodging. It is often impossible to obtain help at $3 a day. Upon the whole, the present dissatisfaction with labor is having a salutary effect upon the country and matters are gradually adjusting themselves. Farming on a large scale is declining, because of the lower prices for grain, the inefficiency of labor and the high wages demanded by it. The large farms are being cut up to furnish homes for the many, farming is becoming more diversified and better methods of cultivation are being introduced.

Wheat, flax, barley and oats have been and are the chief products of the region. The heavy loamy and clay soils of the valley are recognized as being especially adapted to these crops and the seasons are favorable. Formerly it was believed that the seasons were too short for corn, but a variety has been acclimated to the region and now thousands of acres of it are grown yearly. Corn and barley are being grown more and more every year, and hogs are being raised. This is an industry which is becoming important. Last year many carloads of hogs were shipped out of the Red River valley to the Minneapolis, St. Paul and Chicago markets.

The transportation facilities of the area are very good, the main line of the Northern Pacific passing through its entire length from east to west. A branch of this road, known as the Fargo & Southwestern, runs from Fargo to Lisbon, crossing the southeastern part of the area. The main line of the Great Northern crosses the area at Fargo and a branch of that line crosses at Casselton. Along these roads at intervals of about five miles are sidetracks with platforms and at many of these shipping points there are elevators for storing grain. Many farmers load their grain directly into cars from the platforms, while some store it in the elevators to await future shipment.

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SOIL SURVEY OF JAMESTOWN AREA.

BY THOMAS A. CAINE AND A. E. KOCHER.

(Field operations, bureau of soils, 1903.)

LOCATION AND BOUNDARIES OF THE AREA.

The Jamestown area is located in the east central part of North Dakota and comprises parts of Stutsman and Barnes counties. It is included within meridians 98 degrees and 98 degrees, 53 minutes and 34 seconds west longitude and 46 degrees, 48 minutes and 15 seconds and 46 degrees, 58 minutes and 41 seconds north latitude and is made up of townships 139 and 140 north, ranges 58 to 65, inclusive, west.

The area has an extent of approximately 496 square miles, or 317,760 acres.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The experiences of the early settlers of the area were similar to those of all the early settlers of the northwest. The earlier permanent settlements were made in 1871, after the Northern Pacific railroad had penetrated the region. In 1872 the city of Jamestown was founded by the railroad company. Stutsman county was organized in 1872 under the laws of Dakota territory. The first actual settlements in Barnes county were not made until 1877 and the following year the county was organized with Valley City as the county seat. Prior to 1880 the growth of the town was slow, on account of the embarrassment of the railroad and because of other drawbacks which retarded the settlement of the surrounding country. The very earliest settlements were scattered and for the most part of a transient nature. The long, rigorous winters, the lack of fuel and the blizzards of the early days were hardships hardly appreciated by those now living under the modified conditions of climate with better facilities for obtaining fuel. But from the beginning the growth of the region has been a healthy and vigorous one. The sturdy, industrious class of farmers who came from Scandinavia have done much to bring the region into prominence.

In 1887 a general immigration set into the territory as a whole and the location and productiveness of the area surveyed attracted its full share of newcomers. In 1889 the states of North and South Dakota were created out of Dakota territory. From 1880 to the present time the history of the region has been one of growth and

prosperity. The lands which were either taken up under the homestead act or purchased from the railroad corporations for a nominal sum, have steadily increased in value, and during the past few years have doubled and in some cases trebled in value. In the eastern part of the area the present average price per acre is $25. In the vicinity of Jamestown the average price for the prairie soil is about one-third lower than at Valley City.

CLIMATE.

Owing to the absence of forests and the geographic position of the area, in the center of a large continent, and about equidistant between the north pole and the equator, the difference between the temperature of summer and that of winter is very great. Usually there are only a few days in summer when the mercury gets as high as 100 degrees F., and the nights are always cool. The seasons are sharply separated. Spring comes by a sudden transition in April, when the surface of the ground thaws rapidly, permitting seeding in a few days. Winter comes on by a sudden cold wave in November, when the ground freezes and stops the fall plowing.

During the months of January and February the temperature is often from 10 degrees to 30 degrees below zero for days at a time, but the dryness of the atmosphere makes this low temperature no more difficult to endure than a much higher temperature along the coast or lakes, where the atmosphere is damp.

There is a considerable difference in precipitation between the extreme eastern and the extreme western limits of the area. The records of the weather bureau station at Jamestown cover a period of twelve years and show that the average yearly precipitation is about eighteen inches. The year 1899 was an exceptional year, when the precipitation was as low as 6.75 inches. In 1896 the total rainfall was also exceptional, when it reached 33.09 inches. Although the records at Valley City are incomplete, it is pretty well established that the average yearly precipitation is about twenty-one inches. The chain of lakes in the vicinity of Sanborn seem to affect the conditions of precipitation, for east of these lakes the precipitation is practically the same as at Valley City, while west of them it is about the same as at Jamestown. The subsoils east of the lakes are a trifle heavier and therefore better able to retain moisture. These are facts well recognized by the farmers and all lands east of the lake chains are held at from $5 to $10 more an acre than those to the westward.

The presence of so many native trees along the Sheyenne River is also believed to have something to do with the greater precipitation.

The following table gives the normal temperature and precipitation, so far as available, from the records of the weather bureau stations at Jamestown and Steele:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Jamestown		Steele		Month	Jamestown		Steele	
	Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches		Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches
January.....	9.0	0.53	8.0	0.32	August.....	67.0	1.28	66.0	2.20
February ...	9.0	.56	7.0	.36	September.	58.0	.93	58.0	.76
March.......	19.0	1.00	15.0	.66	October....	46.0	.53	41.0	.39
April........	42.0	2.21	41.0	1.65	November.	22.0	1.15	25.0	.59
May.........	53.0	2.98	54.0	2.44	December..	16.0	.74	14.0	.24
June........	65.0	4.21	63.0	3.42					
July.........	70.0	......	68.0	2.76	Year....	39.7	......	38.3	15.79

The winters are less severe than formerly, the greatest change being in the months of January and February. In these months there has been a decided increase in temperature and a slight increase in the months of March, April and May, while during the remainder of the year the conditions have been more constant. That the winters are milder now than formerly is a fact well recognized by all farmers who have lived in the valley for a score or more of years.

Owing to the difficulty of getting onto the fields early enough in spring to plow for seeding, nearly all plowing is done in the fall after harvest, thus exposing the characteristic black soil of the region to the sun during the winter months, while in the summer months the growing and maturing crops represent more nearly the original prairie condition. This is doubtless one reason why there has not been so great an increase of temperature during the summer as in the months of January and February. The rainfall is greatest during the months when it is needed most by the growing crops, namely, in June and July. During January and February the average precipitation is less than one inch. The small amount of snow that falls during these months is not lodged in the prairie grass as formerly, but is either blown off the plowed fields into the coulees or is melted upon the heat-absorbing black soil during the bright days. Before the country was broken up the snow was held in the

prairie grass, the light-colored grass and lighter-colored snow tending rather to reflect the sun's rays than to absorb them. The conclusion is that the change of temperature is due to the exposure of so much black soil to the sun during the winter months.

On the whole, the length of the growing season seems to be a little longer and therefore the conditions are getting more favorable for corn. This change may be ascribed to the same cause as the milder winters—the exposure of the black soil to the sun. While it is well known that a black soil radiates heat as rapidly at night as it absorbs it during the day, it should be remembered that in this northern latitude during the spring, summer and fall there are more hours of sunshine per day than in latitudes farther south.

The term "killing frost" represents a frost which will kill such crops as are generally grown in the valley and usually represents a temperature of 24 degrees F. If fruits were grown in the valley a much higher temperature would doubtless be regarded as a killing frost.

The records for the past several years show the average dates of the last killing frost in spring and the first in fall to be as follows:

	Last in spring	First in fall
Jamestown	June 1	Sept. 12
Steele	May 27	Sept. 13

PHYSIOGRAPHY AND GEOLOGY.

The entire area was covered with ice during the glacial period. One can form a better idea of this period if he thinks of a great mass of ice flowing or shoving its way across the country from north to south, carrying with it large quantities of granite, gneiss, schist and limestone from Canada, planing off the hills and filling the valleys with the material of the hills. This was not a condition peculiar to North Dakota, but common to the northern states from North Dakota to Maine. When this great mass of ice retreated or thawed away, the ground-up rock fragments which had been carried along by it were left as a mantle over the glaciated region. The thickness of this mantle of glacial till, as it is commonly called, varies in different parts of the glaciated region, but in the area surveyed the average thickness is less than 100 feet.

The topography of glaciated regions varies from comparatively level to hilly and broken. With the exception of the morainic hills south of Sanborn the surface in this area may be classed as level prairie. It is characterized by its gently undulating surface, made up of a succession of low hills and knolls and shallow depressions, with a few glacial bowlders and some gravel strewn upon the surface and disseminated through both soil and subsoil.

From the extreme eastern to the extreme western limits of the area, a distance of forty-two miles, there is a gradual rise westward of about 125 feet. This gradually rising and gently undulating prairie is broken by two deep gorges, where the James and Sheyenne rivers have cut their channels. The waters of the former stream eventually reach the Gulf of Mexico, while those of the latter flow into Hudson Bay. The divide between these two systems of drainage crosses the area at Eckelson. Jamestown, on the James River, has an altitude of 1,400 feet and is 115 feet below the top of the prairie, while Valley City, on the Sheyenne, has an altitude of 1,221 feet and is over 200 feet below the prairie. The lowest point in the area is 1,200 feet above sea level, while the highest point is on the terminal moraine south of Sanborn and has an altitude of 1,600 feet, so that there is a range in elevation of 400 feet in the area.

The James and the Sheyenne rivers are now small and sluggish, and it was during the glacial period, when they were swollen with the waters of the melting ice, that their deep gorges were cut. The bluffs along the James are made up entirely of glacial till, the underlying Cretaceous rock of the county being exposed only in the lower places along the stream. These bluffs are characterized by their serrated appearance and also by the fact that their steep sides are strewn with glacial bowlders of all sorts and sizes. The bluffs along the Sheyenne river have an entirely different appearance. Their tops are capped by only a thin mantle of glacial till. The line of separation between this till and the underlying Cretaceous shales can be traced by the difference in vegetation above and below the line. Above the line the bluffs have the appearance of those along the James, being serrated and covered with glacial bowlders, and because of the slight rainfall and extreme conditions of drainage, devoid of all vegetation except a scanty growth of grass. Below the line the numerous springs which come out on top of the

Cretaceous shales furnish sufficient moisture for a natural vegetation of oak and other hardwood trees.

Between the James and the Sheyenne rivers are several dry waterways which cross the area in a north and south direction. None of these waterways are more than 40 feet deep. They are fairly well defined and doubtless served as avenues for carrying off a great deal of water from melting ice to the northward during the glacial period. Some of these old water courses are cut into the underlying Cretaceous rock, and they may represent preglacial channels that were not so completely filled with glacial material during glacial times but that they still served to carry off the water from melting ice. Water has not flowed through these valleys within the memory of man, and they are now entirely dry, except in the depressions which are considerably below the natural avenue of drainage. Water usually collects in these depressions, and often a series of lakes may be traced along these old water courses. Such a chain consists of Fox, Rose, Goose and Mud lakes.

The lakes mentioned above have no outlets and their waters contain a great deal of alkali. Goose and Mud lakes are very shallow and often become dry by evaporation in the summer. The alkali, which was in solution, is then left as a white deposit along the shores and dry bottoms of these lakes, but when the wet season returns these salts are again taken up. If the waters of these two lakes were drained off and the salt not allowed to accumulate, their mud bottoms would probably become valuable for the production of hay.

A characteristic of all these lakes is that they have a distinct fringe of sand, gravel and bowlders along their shores. This was such a distinct feature and so much ground was covered with shore bowlder-chains that it was indicated as a distinct type in the soil map. Its origin can be traced to the sand, gravel and waterworn rocks and pebbles strewn along old water courses. The sand and gravel along the lakes are composed of this material sorted by wave action of existing lakes, but the long line of accompanying bowlders is acounted for by a different phenomenon. During the intensely cold winters these shallow lakes freeze to their bottoms. The rocks and bowlders in the bottom are frozen into the ice. Large cracks appear in the ice and during the warmer days these cracks are filled with water, which freezes and expands. The result is a pushing of

the ice upon the shores and the carrying of the rocks a little farther shoreward with each successive winter. The finer material along the bottom is also frozen into the ice, and when the ice breaks up in the spring it is carried along in the direction of the prevailing wind. The sand and gravel thus accumulated are reworked by the waves and piled up by them, forming beaches.

SOILS.

The location of the area about midmay between the lands used exclusively for grazing and those used for grain growing makes it representative of the types of soil and the conditions of climate over a very large and important part of the state.

The following chapters give a description of the soil types met with in the area and the appended tables shows the extent of each of these types and the proportion which each bears to the total area.

AREAS OF DIFFERENT SOILS

Soil	Acres	Per cent	Soil	Acres	Per cent
Marshall loam	206,976	65.1	Meadow	4,992	1 5
Marshall silt loam	41,280	13.2	Hobart clay	3,712	1.1
Marshall stony loam	30,208	9.5	Sioux clay	2,432	.8
Riverwash	17,408	5.5			
Sioux fine sandy loam	5,632	1.7	Total	317,760	....
Miami black clay loam	5,120	1.5			

MARSHALL STONY LOAM.

The Marshall stony loam has an average depth of about seven inches of drak-brown, loose, sandy or gravelly loam. Occasionally there is present an admixture of considerable clay loam, and again the interstitial material may be almost wholly coarse sand. The surface soil is underlain to a great depth by unmodified glacial till Disseminated throughout both soil and subsoil and scattered in large quantities on the surface, are glacial bowlders of all sorts and sizes. This type is in nearly all cases associated with the abandoned waterways and with the moraines which are scattered over the entire area but are especially numerous south of Sanborn. It also occurs as narrow areas encircling Miami black clay loam. Here the soil represents beaches of old lakes or ponds.

This type is also found on the sides of all the serrated bluffs of the James river and on the sides of the deep coulees which lead into this river. Along the Sheyenne in the vicinity of Valley City and to the southward this type is found only on the tops of the bluffs,

the lower part of the bluffs being composed of the Cretaceous shales. On the river northwest of the town the glacial till has been spread as a mantle over the entire bluffs from top to bottom and in such locations the conditions are the same as those on the sides of the bluffs of the James river.

The moraines represent places where the edge of the melting ice sheet stood for some time. The character of the material thus accumulated varies. Sometimes it is quite sandy, nearly always it is very stony, while occasionally it is very nearly the same in texture and appearance as the Marshall loam found on the level prairie, but because of the slight rainfall, and owing to its elevated position or its great porosity, it is too dry to be of any great agricultural value except as pasture.

South of Sanborn some of the morainic hills mapped as this type rise to an elevation of 200 feet above the surrounding prairie. The subsoil in some of these hills is not unlike the soil on the level prairie, but the soil on their steep slopes has been so washed that nothing but the coarser constituents are left, the finer particles having been carried down into the valleys between the hills. Occasionally fair crops are grown about half way up the sides of some of these hills, depending upon the season and the local conditions of moisture, but considerable areas are of no value except as pasture lands.

A phase of the Marshall stony loam consists of a dark-brown or black loam, with an average depth of twenty inches, underlain by a subsoil of coarse sand or gravel. As in the type riverwash the subsoil often persists to a great depth. Disseminated throughout the soil and subsoil are large glacial bowlders. In the soil there is usually present considerable organic matter derived from the luxuriant grasses which grow in such locations. In the lower depth of the subsoil, at about fifteen feet below the surface, there is often one or two inches of bluish-gray silt or clay.

This phase is found in the bottoms of the "dry waterways" which were avenues for the water from melting ice in glacial times. It differs from the riverwash chiefly in that the latter is found in higher locations and is dry throughout the year and therefore of little agricultural value except as a scanty pasture. It differs from the areas mapped as meadow in that the latter are too low and marshy to be of much agricultural value under present conditions.

In all cases the surface soil of this phase is a wash of the finer sands and silts from the higher surrounding prairie and is a veneering over the wash left at the close of the glacial period. In a few locations the lowest slopes of the typical Marshall stony loam have been veneered over by a wash from higher grounds. As in the case of the typical stony loam, there are sometimes numerous large bowlders protruding above the surface.

This phase of the Marshall stony loam, occupying as it does the lower, but not the lowest parts of the old water courses, usually contains plenty of moisture during the greater part of the year. In times of excessive rain, however, it is usually very wet and occasionally flooded, while during the long-continued drought it may become very dry because of the loose, porous nature of the subsoil. Because of this and because in some locations there are injurious amounts of alkali, it is not a desirable soil for cultivated crops. The type seems usually well adapted to grains and pasture and is used almost exclusively for these purposes. It would doubtless be better if no attempt were ever made to put this type under cultivation. It is now one of the most valuable types in the area for grass, and since so much of the prairie has been broken and the prairie grass destroyed there is an increasing demand for hay.

The following table shows the texture of samples of the fine earth of the Marshall stony loam:

MECHANICAL ANALYSES OF MARSHALL STONY LOAM

No.	Locality	Description	Organic matter — per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9159	4½ miles SW. of Eckelson	Brown loam, 0 to 8 inches	5.27	3.82	8.22	8.16	23.56	20.42	28.42	7.38
9161	Valley City	Brown stony loam, 0 to 30 inches	10.57	3.18	5.68	4.98	20.90	21.8	36.04	7.42
9162	Jamestown	Loam, 0 to 6 inches	7.12	4.12	7.42	7.00	20.82	15.42	34.54	10.50
9158	2½ miles S. of Eckelson	Brown gravelly loam, 0 to 8 inches	3.93	2.28	8.70	10.42	28.66	15.08	22.78	12.06
9160	Subsoil of 9159	Light brown loam 8 to 30 inches	3.60	3.10	7.82	7.12	20.36	17.56	29.88	13.94
9163	Subsoil of 9162	Sandy loam, 6 to 40 inches	2.39	3.92	7.20	7.38	20.38	12.76	28.52	19.74

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9158, 15.20 per cent; No. 9160, 1.62 per cent; No. 9161, 6.30 per cent; No. 9163, 4.60 per cent.

MARSHALL SILT LOAM.

The surface soil of the Marshall silt loam consists of a dark-brown to black loam with an average depth of ten or twelve inches. The subsoil is slightly more silty and clayey in texture and varies in color from dark brown to brown, usually becoming yellowish brown in the lower depths.

Scattered upon the surface and disseminated through both soil and subsoil, are fragments of rock varing in size from fine gravel to large glacial bowlders. These, however, are not so numerous as in the case of the Marshall loam.

This type is typically developed on the level prairie about 200 feet above the Sheyenne river, in the vicinity of Valley City and in its most typical phase extends back from one and a half to three miles on each side of the bluffs. These narrow strips represent the flood plain of the river in glacial times. In its least typical phase the soil extends several miles back from the river, but only a small part of the region east of the river was included within the area. It reaches west as far as Sanborn and Hobart lakes and to the foot of the morainic hills immediately south of these lakes. The dividing line between this type and the Marshall loam leaves the area about two miles northwest of Sanborn.

In its topographic features it is much more level than the Marshall loam and in the narrow strip on each side of the Sheyenne river it has been considerably cut up by ravines and coulees, but the outline of the original level can be traced for miles. Back from the river some distance its topography becomes gently undulating and is marked by a succession of low hills and shallow depressions locally known as "bog holes."

The origin of this type is glacial, as in the case of the Marshall loam, but it differs from the latter in that the underlying Cretaceous rock is in some cases very close to the surface and has entered very largely into the composition of the soil. This accounts for its being heavier in texture than the Marshall loam.

This type retains moisture better than the Marshall loam.

For general farming purposes this soil has no equal in the area. It is all under cultivation and is held at about $30 an acre. Thirty-five bushels of wheat is not an unusual average yield. Flax, oats and barley do comparatively well.

In some places in this type there are occasional small patches on which the grain becomes partially choked off, an effect due to the gumbo characteristic of the soil. These areas are not large enough to interfere seriously with the value of this type.

The following table shows the texture of typical samples of the fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL SILT LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9167	2 miles E. of Sanborn..	Loam, 0 to 8 inches	7.58	2.00	8.32	8.18	27.56	15.90	31.06	6.84
9165	4 miles E. of Hobart...	Gray silty loam, 0 to 12 inches..................	3.41	.12	.76	1.32	5.36	6.42	74.42	11.00
9168	Subsoil of 9167	Loam, 8 to 40 inches	4.04	2.86	10.80	10.24	30.08	13.16	24.56	8.22
9166	Subsoil of 9165	Yellow silty loam, 12 to 40 inches...............	3.15	.10	.32	.30	1.32	2.50	80.00	15.18

The following samples contained more than one-half per cent of calcium carbonate ($CaCo_3$); No. 9166, 14.15 per cent; No. 9168, 0.60 per cent.

SIOUX CLAY.

The soil of the Sioux clay is a black to dark-brown or sometimes yellowish-brown, clay loam or clay, with an average depth of eighteen inches. The subsoil is a grayish-brown to grayish-yellow, stiff, waxy clay loam or clay, with a depth of several feet. The difference between the soil and subsoil is that the former has more organic matter incorporated with it and is a little more sandy.

The Sioux clay is a type confined to the bottoms of the Sheyenne river, from the vicinity of Valley City southward to beyond the southern limits of the area. The soil is partly of alluvial origin and partly a wash from the Cretaceous bluffs which rise about 150 feet on each side of the river. The residual soil formed from the weathering of the soft shale in these Cretaceous bluffs has all of the characteristics of the gumbo found in the Red River valley. It is exceeding slippery under foot, is very waxy and gummy and has a greasy, oily feel. The Red River valley gumbo is doubtless the same material carried in suspension by the glacial waters and redeposited in glacial Lake Agassiz. But there are no large bodies of this residual soil, since in its redeposition along the river it has all been

more or less intimately mixed with a small amount of fine sand that has found its way down from the higher prairie. In some places the type varies from a fine friable loam to a stiff silty clay, having the objectionable features of gumbo.

This type, with the exception of a few gumbo spots which bake and dry out during a dry summer, is excellent for truck farming as well as for the growing of small grain. Under the best of conditions wheat sometimes yields as much as forty bushels per acre upon this soil. Oats and flax also do remarkably well. Only about one-half of this type is under cultivation, the remainder being occupied by a growth of oak, elm, ash and other indigenous trees.

Where cultivated this type is used largely for growing small grain and millet. The shelter afforded by the trees would make it one of the most desirable locations in the state for growing orchard fruit and berries.

The following table shows the texture of typical samples of this soil:

MECHAICAL ANALYSES OF SIOUX CLAY

No.	Locality	Description	Organic matter — per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9176	Valley City	Brown loam, 0 to 36 inches	0.67	0.0[illegible]	0.16	0.28	3.52	0.9[illegible]	58.66	25.88
9174	3 miles S. of Valley City.	Clay loam, 0 to 12 inches	5.23	.00	.3[illegible]	.82	5.6[illegible]	4.52	32.0[illegible]	6 64
9175	Subsoil of 9174	Clay loam, 12 to 40 inches	.19	.06	.56	1.9[illegible]	8.92	5.30	30.80	52 34

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9174, 4.55 per cent; No. 9175, 14.10 per cent; No. 9176, 8.20 per cent.

HOBART CLAY.

The Hobart clay consists of from one inch to four inches of a gray or dark-brown clay, underlain to a depth of three or four feet by heavy drab-colored clay. In the lower depth of the subsoil the clay is more or less intimately mixed with fragments of the underlying Cretaceous shale. Below the fourth foot the shale is found in various stages of disintegration, until finally the solid rock is reached. The harder parts in the shale or such parts as are more resistant to the agencies of weathering are frequently seen strewn upon

the surface. This accounts for the presence of small fragments of gypsum, "iron" shale and calcareous and fossiliferous shale. When the soil is wet it is very adhesive and slippery under foot and has a greasy, oily feel. In dry weather it often bakes and growing crops are often injured in this way. In a few places along the steepest bluffs the shale has not weathered sufficiently to support any vegetation, and at such places small landslides frequently occur. In places such landslides have carried down the glacial till from above.

A peculiar feature of this type, and one which is not common on any other type in the area, is the occurrence of numerous fresh-water springs, formed by the water soaking down through the porous soils resting as a mantle upon the Cretaceous shales until the impervious clay and shale are reached, when it flows laterally and issues from the sides of the hills.

Owing to the stiff, tenacious character of the soil and its location upon the steep sides of the bluffs, this type has very little agricultural value except as a pasture for sheep and cattle. Owing to the numerous springs it supports a good growth of pasture grass. There is a use, however, to which this type is well adapted, and that is the growth of forest trees. Wherever there is a spring on the hillside and along every ravine which carries water, there is to be found a good growth of oak, ash, elm and other hardwood trees. At Valley City this type is covered by such a growth.

The following table gives mechanical analyses of this type of soil:

MECHANICAL ANALYSES OF HOBART CLAY

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9178	6½ miles S. of Valley City	Clay, 0 to 60 inches	0.42	0.00	0.08	0.06	0.40	1.08	19.28	79.10
9177	Valley City	Clay, 0 to 60 inches	.88	.42	.54	.18	.48	.84	8.02	89.52

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9177, 0.78 per cent; No. 9178, 18.40 per cent.

SIOUX FINE SANDY LOAM.

The Sioux fine sandy loam consists of from one foot to two feet of very fine sandy loam of dark-brown to grayish color, resting on a subsoil of the same texture with a depth of several feet, but changing in color at about the third foot, where, out of reach of decaying organic matter, it becomes gray. The Sioux fine sandy loam is found in the James river and Sheyenne river valleys and is of purely alluvial origin, being a wash of the finer sands of the prairie type, Marshall loam, deposited as sediment in times of high water or when these streams stood at higher levels. In the James River valley, in the vicinity of Jamestown, this type is closely associated with the type Riverwash, upon which the city itself is built. The latter type was deposited in glacial times when the James river was a torrent, while the type under discussion is a post-glacial deposit and overlies the former.

This soil, though quite limited in extent, is one of the most desirable in the area. Because of its location, it is usually well supplied with moisture, even in the driest season. This fact, together with its fine, loose, loamy texture, makes it well adapted to all farm crops of the area.

Wherever this soil is found it is under cultivation. The average yield of wheat is twenty-five bushels per acre, but forty bushels is not an uncommon yield. Flax averages twenty bushels, the average yield for barley is forty bushels, and oats sometimes yield as high as seventy bushels per acre. In the vicinity of Jamestown the soil is used extensively to supply the local demand for truck. The corn which is being acclimated to the region seems to do especially well upon this type, sometimes yielding as high as sixty bushels per acre. In the vicinity of Jamestown some alfalfa has been successfully seeded upon this soil. It is also well adapted to millet, pigeon grass and brome grass.

In a few cases this type has been irrigated and as it lies convenient to the rivers more of it will probably be brought under this form of cultivation in the future. The results from irrigated areas have so far been very satisfactory.

The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

MECHANICAL ANALYSES OF SIOUX FINE SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9140	3¼ miles SE. of Jamestown	Fine sandy loam, 0 to 15 inches	1.21	0.10	2.92	14.74	52.04	14.00	11.70	4.10
9142	Jamestown	Fine sandy loam, 0 to 14 inches	2.12	2.10	9.02	7.34	28.50	18.06	26.44	8.40
9141	Subsoil of 9140	Fine sandy loam, 15 to 36 inches	.87	.14	1.70	7.34	37.56	23.16	25.02	4.90
9143	Subsoil of 9142	Fine sandy loam, 14 to 30 inches	1.90	3.94	9.36	7.70	27.04	16.92	24.94	9.58

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9140, 3.99 per cent; No. 9141, 9.27 per cent.

MIAMI BLACK CLAY LOAM.

The Miami black clay loam is of a very silty or clayey texture and has an average depth of twelve inches. The color of the soil varies from dark brown to black, depending upon the amount of organic matter present and the state of its decomposition. The subsoil to a depth of three feet or more contains more clay than the soil and has less organic matter incorporated with it. Its color varies from dark brown to gray. A few concretions of iron oxides were found in the lower depths of the subsoil.

The Miami black clay loam is more or less widely distributed over the entire area and is found in depressions that were at one time ponds or small shallow lakes. There are usually little beaches of sand and gravel and some larger rocks around the outside of these depressions, showing that at some former time they were filled with water.

Since the first breaking up of the prairie some of these low wet places have been reclaimed and are now among the most productive lands of the area, and eventually all the shallow lakes of the area will give place to tracts of this soil. Probably not more than one per cent of this type is under cultivation. The type is especially adapted to the growing of hay.

Since the breaking up of the original prairie and the destruction of the prairie grass, the problem of hay production has become very serious. It would be better never to put the areas mapped as Miami

black clay loam under cultivation, but to reserve them as meadows.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1—mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9154	1 mile NE. of Spiritwood	Black clay loam, 0 to 12 inches	8.74	0.32	4.74	6.80	13.90	12.04	45.30	16.58
9156	2 miles NE. of Eckelson.	Black silty loam, 0 to 24 inches	3.32	.28	1.22	1.72	7.02	12.32	56.48	20.96
9157	Subsoil of 9156	Gray silty loam, 24 to 40 inches	3.00	.22	.64	.88	3.70	7.84	57.26	29.38
9155	Subsoil of 9154	Silty loam, 12 to 40 inches	4.26	.18	.52	.90	3.58	7.28	56.16	30.98

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9154, 2.71 per cent; No. 9155, 4.78 per cent; No. 9157, 10.40 per cent.

MARSHALL LOAM.

The soil of the Marshall loam is of brown to dark brown color, has an average depth of seven inches and varies in texture from a medium fine to fine sandy loam. The first foot of the subsoil is usually of the same texture as the soil, but the material becomes somewhat heavier as the depth increases. The color of the subsoil when dry ranges from light brown in the first foot to gray in the second foot, becoming yellowish when wet. The dry subsoil heaped around the mouths of gopher and badger burrows presents an appearance not unlike that of wood ashes. Scattered upon the surface and disseminated through both soil and subsoil are fragments of rock varying from the size of a pea to large glacial bowlders.

This is the most extensive type in the area. It is typically developed east and west of Jamestown. The topography is gently undulating, marked by a succession of low hills, knolls, and shallow depressions locally known as "bog holes." In many places the latter are too wet and swampy to admit of cultivation, but since the breaking up of the prairie soil of the region many of these have become so thoroughly dried out that they are cropped with the same ease as the higher prairie soil adjoining. In several places in the area, especially in the region south of Sanborn, this type of

soil is marked by morainic hills, a few of which rise to 200 feet above the adjoining prairie.

The tops of these moraines, both on account of excessive drainage and the lighter texture of the soil, are very subject to drought and hence are of little agricultural value except for pasture. The lighter texture of the soil is due to the fact that the finer particles have been washed down to lower lying lands. This same fact accounts for the heavier phase of Marshall loam in the depressions between the morainic hills. The fact that nearly the whole area is a region of little definite drainage is very beneficial because the rain, instead of being carried off by streams and coulees, is allowed to soak into the ground. Along the James river and Ten Mile coulee, east of Jamestown, the evil effects of extreme conditions of drainage in a region of slight rainfall are plainly apparent. For a distance of from one-half mile to two miles on each side of these streams the type under discussion is so dry as to be almost worthless except as pasture, supporting only a scanty growth of wild grasses.

South and west of Jamestown only about one-half the area of this soil has ever been cultivated, while farther east it is nearly all under cultivation. The unbroken areas are covered with a dense sod of very nutritious natural prairie grass. In the depressions, where the conditions of moisture are better, this prairie grass grows very luxuriantly, and is very valuable for hay. In those parts of the area where this type is all under cultivation the need of prairie hay is sorely felt, and millet is being quite extensively grown to supply the deficiency.

Wheat, flax, oats and barley are the leading crops, and to these this soil, in a favorable season, is well adapted. In good years wheat gives an average yield of twenty bushels per acre, but under the most favorable conditions it sometimes gives as much as thirty-five bushels. The average yield of flaxseed is about fifteen bushels, but this crop has been known to yield as much as twenty-five bushels per acre. The average yield per acre of barley is about thirty bushels, and that of oats about forty-five bushels. A variety of corn is being acclimated to the type, and with a fair amount of rain and a season of ordinary length promising results are obtained.

The following table gives mechanical analyses of typical samples of fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9148	1 mile S. of Eckelson....	Fine sandy loam, 0 to 12 inches	3.91	0.88	2.30	2.16	6.60	10.50	62.72	14.50
9150	5 miles E. of Spiritwood..	Fine sandy loam, 0 to 14 inches	3.32	1.91	5.96	6.12	15.80	13.50	41.04	15.08
9149	Subsoil of 9148	Fine sandy loam, 12 to 40 inches	.64	6.14	9.62	7.44	18.18	12.02	29.58	16.74
9151	Subsoil of 9150	Fine sandy loam, 14 to 36 inches	1.90	2.5[illegible]	6.70	5.58	12.06	12.68	39.92	19.42

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$); No. 9149, 18.60 per cent; No. 9151, 12.97 per cent.

RIVERWASH.

The riverwash consists of about twelve inches of brown or grayish-brown sandy loam underlain with coarse sand and gravel, loose shale and large shale boulders, often to a depth of fifty feet. The soil is merely a wash of fine sand from adjoining bluffs and prairies, and is a veneer over the coarse, loose, porous sand and gravel which underlies it. The subsoil consists entirely of a collection of coarse sand and gravel in the protected places along the streams when these were glacial torrents. For example, the coarse sand and gravel upon which the city of Jamestown is built was deposited on the inner bend of the river at that point. The same cause is assigned for the accumulation of the great quantities of sand and gravel in the vicinity of Valley City.

This type is also found in various parts of the area between the James and Sheyenne rivers. It is here associated with old waterways, probably unused since glacial times.

The type is locally known as "second bench land" and except for pasture is held in low esteem for agricultural purposes. In some places it is so dry that it does not furnish sufficient grass even for pasture.

MEADOW.

The areas mapped as meadow represent a condition of low, marshy depressions found in the lowest portions of the valleys outside of the James and Sheyenne valleys. The reason that no such

conditions exist along the courses of these streams is that their system of drainage is well established and there are no marshy depressions adjoining them. The type meadow is found most extensively along the "dry waterways" in the region between the James and Sheyenne rivers and represents a condition where no definite system of drainage has been established since the retreat of the ice sheet.

The meadow is closely associated with the type riverwash and Marshall stony loam, since they are all found along abandoned water courses; but it differs from the riverwash in that the latter is higher and looser in texture and, therefore, too thoroughly drained, and from the deeper phase of the Marshall stony loam in that the latter type is a little higher and adapted to the production of hay and for pasturage.

The areas mapped as meadow support only the coarsest and rankest kind of marsh grass, which has no value whatever as hay and very little as a pasture food. Under the present conditions these areas have no agricultural value except as watering places for stock, and often the water is too alkaline for that purpose. In most locations the conditions would be greatly improved by artificial drainage.

AGRICULTURAL METHODS.

The early settlers who came from the east found conditions in the northwest very different from those they left. In the area surveyed, and in the adjoining prairie region, there were no forests to be cleared and no rocks to be gathered. The pioneer had simply to build his sod house and barn, both of which were sometimes under the same roof, turn up the rich virgin soil of the prairie, and sow his seed.

The first "breaking" of the prairie sod was always shallow and with a single plow. The work of breaking began as early in the spring as possible and extended into July and August. The virgin sod is so tough that only the single plow can be used. The shallower the plowing the better, provided the grass roots are cut just below the main root. During the summer months the sod becomes thoroughly rotted and pulverizes readily when the ground is turned again in the fall. Fall plowing begins about the middle of August and continues until frost. The next spring, as soon as possible.

wheat is sown with a seeder and this is followed by a smoothing harrow. Flax is the only crop ever sown in the spring after the first plowing, because it is then too late for wheat or other small grain. Because of the fungus disease popularly known as flax wilt, flax is seldom sown upon any but new land and then only for a year or two.

After the prairie has once been broken all plowing is done in the fall. This is usually done with a gang plow, turning two furrows at a time. In order to fill the air spaces and thus prevent the furrow slices from drying out, the plow is sometimes followed by a smoothing harrow, and sometimes the plow has a harrow attachment, thus doing all the work at once. The ground is harrowed once in the spring before drilling. Wheat is sown as the first crop in the rotation. It is followed by barley and then by oats. The most successful farmers let the lands lie fallow during the fourth summer, bringing up at that plowing an inch or so of the new soil. In this way the new soil is acted upon by the weather and also by the soil bacteria during the summer and winter months. Some cultivated crop like corn is considered nearly equivalent to summer fallowing.

As yet no commercial fertilizer has ever been used in the area, and until recently many farmers have drawn their manure out in piles and burned it, believing it to be more injurious than beneficial to the soil. In the early days it had a tendency to make the growth of straw too rank, but since the productiveness of the soil has declined through constant cropping, manure has been found to have a decidedly beneficial effect. When coarse manure is turned under it has a tendency to make the soil too dry, and the manure is often drawn out in piles and allowed to rot and disintegrate before using. One popular method is to spread it upon the ground after the fall plowing and allow it to leach into the soil during the winter and spring months. Before seeding the coarse litter is sometimes raked up into piles and burned.

AGRICULTURAL CONDITIONS.

The value of the soils of the area in the production of wheat, flax and other crops is shown by the prosperity of the farming class. Until recently the thoughts of the farmers were taken up with the acquiring of land. This accomplished and a few successful crops

harvested, they have turned their attention to improving the land and beautifying the home. The sod house and barn of pioneer days have been replaced by wood and stone structures, and most of those who have been in the area for any length of time have built for themselves good, substantial houses. As yet there are only a few large barns in the area, which may be accounted for by the practice of threshing directly from the field and taking the grain at once from the machine to the elevators or cars. The necessity of large barns and sheds, however, is felt wherever stock raising is carried on as an auxiliary to grain growing. One thing which has retarded the building of large barns has been the high price of building material, nearly all of which must be brought long distances from the states of Oregon and Washington.

Ten years ago the unbroken prairie land could be purchased for $7 an acre. At that price some paid for their farms with the profits of a single crop. All those who availed themselves of the opportunity to purchase, if they have been industrious and economical, have now a good bank account and a farm clear of incumbrance, with ample stock and machinery for carrying on all farm operations.

Since then land values have been increasing, and without any additional expense on the farmer's part the value of the farm has in nearly all cases doubled and in some cases trebled. Nearly all the land in the eastern part of the area has more than doubled in value, and at present the average price is about $25 an acre. In the western part of the area, in the vicinity of Jamestown, only about one-half of the prairie has been successfully put under cultivation, and the prices range from $10 to $20 an acre, depending upon the nearness of the farms to Jamestown, or on their adaptability to the crops of the region. The days of unlimited range have ended, because the country is so thickly settled, but there are still many cattle grazing upon the prairie west of Jamestown. The land values in the western part of the area have also doubled and in some cases trebled during the past ten years, and in the future there is bound to be a continued increase in the value of agricultural lands throughout the region.

The farms of the area are nearly all operated by the owners. Those worked by tenants are rented for periods of from one to three years. It is not usual for a man of industry and economy to

work as a tenant for more than three years, because by this time he is usually able to take up a quarter section in his own name. In a locality like the morainic hills southeast of Sanborn, where the farms are rented to tenants year after year, it is usually an indication that the lands are undesirable for growing crops. In consideration for the use of his land the owner receives a share of the crop. The proportion is usually one-half of the crop where the owner furnishes half the seed and pays one-half the threshing bill. Owing to the uncertainty of the seasons, either from drought, hail or frost, it is very unusual for the tenant to pay cash rent, preferring to take the chances of getting a reasonable profit for his labor from a half crop. In prosperous times the owner usually prefers to operate his own land, because the profits are so great, and a general desire on the part of owners to rent their farms usually indicates either a series of unfavorable years or inferior land.

The size of the farms varies from 160 to about 2,000 acres, the average size being 320 acres. Smaller farms than these do not contain enough pasture for stock, and for the ordinary man a larger farm than half a section makes it necessary to hire so much help that the profits are destroyed. The prosperity of Jamestown and Valley City and the small intervening towns is in no small part due to the fact that there are no such large farms as in the Red river valley, and that the farmer, instead of bending all his energies to seeding the largest possible area, devotes more time to a better preparation of the soil. Under this system the profits in any one year may not be so large, but they are more certain.

Although the average size of the farms in the area is only 320 acres, there is a tendency toward still smaller holdings and better methods. In the western part of the area, where the rainfall is less than in the eastern part, and where, also, the soils are lighter, the most successful farmers have learned that they must combine stock raising with general farming if they are to avoid failure in unfavorable years. Where stock is kept and good use is made of the manure much better crops are produced.

The labor problem becomes a very difficult one to solve in some years, especially when the farmer owns so much land that he is obliged to hire a great deal of help to handle the crops. During ordinary seasons the demand for day laborers is met by the large force of men who come into the state from all parts of the east and es-

pecially from the nearby eastern states. But in years of exceptional yields the demand for men is greater than the supply and under such circumstances the wage of labor becomes almost prohibitive. Since these men remain in the state for but a few weeks, at most, they often take little interest in their work and their general efficiency is low. The average rate of wages paid to harvest hands for the last five years is about $1.75 a day. The average for the past two years is $2.25. Occasionally $2.50 is paid, but this is not usual. The tendency is toward still higher wages, and since the price of farm products has gone down the farmer can not afford to hire. This is having a salutary effect upon the prosperity of the county. The farmer is learning that it is never profitable to have more land than he and his family can work, or at least no more than he and one man hired by the year can work. The usual wage by the year is $30 per month, with board and lodging.

Owing to the severity of climate no winter wheat is grown. Macaroni wheat has been introduced, and though it commands a price considerably below that of other wheat, the fact that it yields about a third more is making it popular. Since recent experiments have demonstrated the value of the bread made from this wheat, strong influence has been brought to bear upon grain dealers to recognize its value, and it bids fair soon to become an important rival of the older varieties of wheat.

Flax has always been one of the important crops of the area, standing next to wheat. As yet the farmers have not had as serious trouble with flax wilt as have the farmers in the Red River valley. However, it is well recognized that flax is a crop very exhausting to the soil, and that it will not do to crop with flax continuously for more than two years in succession.

Oats and barley are among the profitable grain crops of the area. As yet only a small quantity of corn is grown. The principal difficulty with this crop is that the season is not quite long enough. The variety grown is a small, inferior kind, but by careful selection of seed and breeding much has been accomplished toward getting a variety better in quality and better adapted to the short, cool growing season.

From the appearance of sugar beets seen in gardens it would seem that this crop might be added to the products of the area, but the practicability of establishing this industry on a commercial

scale should be proved by ample experiments both in growing and in determining their sugar content.

As yet but a few tame grasses have been grown in the area since so much of the prairie grass lands has been brought und tivation the problem of hay production is becoming very s Brome grass has been sown by some with a fair degree of and with utter failure by others. The experiments with it to show that with careful preparation of the soil it will bec valuable grass for the region. Alfalfa has been seeded on one in the area, but the experiment has not been under way long e to decide definitely how profitable a crop it will prove to be. S it would seem that it can be successfully grown. The nativ grown in the sloughs and marshes is tall and coarse, though i allowed to become too ripe is very nutrious and makes exc feed for both cattle and horses. That produced upon the h and drier soil is fine and short and is considered somewhat p in quality than the product of the lowlands. The average pri unbaled hay is about $5 a ton. Millet is grown quite exten for hay. The quality is good, but it is almost entirely for c not being considered a desirable feed for horses. Potatoe grown for local consumption. In quality and size they are sc excelled by those grown anywhere. The average yield is abou bushels per acre. No potatoes are shipped out of the area be of the great distance to markets.

Owing to the constant demand for grain, the farmers of this tion are always sure of a ready market for their crop. Two mills, one at Valley City and the other at Jamestown, together sume more wheat than is grown within the area surveyed. not all of the wheat is sold to these mills. The numerous el tors along the railroads, by their active competition with the m cause large quantities of wheat to find a market at the mills at M neapolis, St. Paul, Duluth or Superior. Later in the season it comes necessary to ship in wheat to keep the home mills runn During the season of 1903 the Valley City mill alone was compe to import 110,000 bushels. A conservative estimate of the amo of wheat that will be ground by the two mills during the sea of 1903 is 1,000,000 bushels. About one-half of the flour is within the borders of the state, one-third of the remainder in the western states, and the remaining amount is shipped largely to

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SUMMARY OF THE REPORT ON THE CANDO AREA

BY E. O. FIPPIN.

During the summer of 1904 a soil survey was made covering 28[illegible] square miles in the southern part of Towner county. (See progress map, figure 1.) The state through its Agricultural and Geological Surveys, cooperated with the bureau of soils of the United States Department of Agriculture, furnishing two men who assisted the bureau's men (for about forty days) in the prosecution of the field work.

This survey included the preparation, on a scale of one inch to the mile, of a soil map showing the area and distribution of the different kinds of soil, and a report describing these soils in their relation to the crops now grown and the agricultural methods in use, together with a discussion of the improvement of agricultural conditions and the development of crops especially suited to the climate and the soils. The map and report will be published and distributed in the usual way by the Department of Agriculture. We are enabled, through the courtesy of the bureau of soils, to give here a brief summary of this report.

The area surveyed includes the southern eight townships of Towner county, and occupies an undulating, treeless prairie, eminently adapted to agriculture, as evidenced by the good average yields of all the crops grown. The general elevation of the surface ranges from 1,475 to nearly 1,600 feet above sea level. The two largest towns are Cando and Maza, on the St. John's branch of the Great Northern railroad.

The drainage system consists of several large, shallow and sluggish streams called coulees. Big Coulee is the main stream, and most of the others empty into it, the water finding its way finally into Devils lake. There are also numerous other small, shallow depressions found on the rolling upland and between the elevations, where water accumulates to form swamps.

The superficial material of the region, in some places reaching to a depth of more than 100 feet, has been deposited through the agency of glacial ice. The original glacial till has subsequently been considerably modified by the floods that attended the retreat of the ice margin. It was this large volume of water passing

through the area that formed the coulees and left the large deposits of fine material which enters into several of the local types of soil.

Five types of soil, differentiated by an examination of the surface material to a depth of three feet, have been recognized. Each is characterized by peculiarities of texture and drainage, and has a distinct crop producing power. Their common characteristic is that they contain a relatively high percentage of organic material, and are consequently dark in color.

Areas of a gravelly soil occupy knolls and ridges slightly elevated above the surrounding country, and because of its porous texture and consequent perfect drainage, it produces light crop yields.

Limited areas of fine, sandy loam were found, generally occupying slightly elevated positions. The soil is of a rather fine sandy or silty texture, and because of its slightly elevated position and good drainage it is an early soil, better fitted to the production of corn and vegetables than to the cereal grains.

Most widely distributed of the types recognized is a loam. The soil consists of about twelve inches of heavy, black, sandy loam or loam, under which are mingled clay and gravel of the glacial till, rich in calcareous material. It is naturally productive soil, but the yields are considerably influenced by the seasons.

Next in extent to the loam is a silt loam, which is found chiefly in the eastern half of the area. It is of a friable texture, easy to cultivate, and withstanding unfavorable climatic influences better than most of the soils. It is best adapted to grain, and on the whole is considered the most productive soil of the area.

Scattered in small patches throughout the area are found the clay soils. These always occupy low, undrained swales, and unless thoroughly drained are unfit for any agricultural purpose other than grazing and hay production.

GENERAL CONDITIONS.

There is a comparatively small amount of alkali in the soils, which is found in the poorly drained positions where the texture is finest. Small spots in the grain fields are occasionally injured. More complete drainage and thorough, careful cultivation will do much to correct this evil. Thorough removal of the drainage water, which holds the salts in solution, will in the course of time

remove much of the excess of salts, and cultivation will tend
prevent its accumulation at the surface by preventing evaporati
The chief factor that controls the crop yields in the area is
moisture supply, and this fluctuates from year to year with
variation in the amount of rainfall. Those methods which
at storing in the soil the largest amount of water, and holding
until such time as it can be made to assist plant growth, give
best yields of crops. Deep plowing and the maintaining on
plowed surfaces of a mulch of two or three inches of loose soil
do much to attain this result.

SOIL SURVEY OF THE MINOT AREA.

By Rex. E. Willard.

Location of the Area. — The area included in this survey
located in Ward county, in the region known as the Mouse Ri
valley. The middle point of the southern boundary of the area
four miles north of the city of Minot. The area surveyed embra
a tract six miles north and south by twelve miles east and west,
contains therefore seventy-two square miles, or 46,080 acres.
comprises two congressional townships, which for convenience
in this paper be described by their congressional designations,
township 156 north, range 82 west, and township 156 north, ran
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History of Settlement. — North Dakota is one of the younger
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through the area that formed the coulees and left the large deposits of fine material which enters into several of the local types of soil.

Five types of soil, differentiated by an examination of the surface material to a depth of three feet, have been recognized. Each is characterized by peculiarities of texture and drainage, and has a distinct crop producing power. Their common characteristic is that they contain a relatively high percentage of organic material, and are consequently dark in color.

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The soil types and the general characteristics of the area here described are thought to be fairly representative of a vast area in Ward, Bottineau and McHenry counties. This portion of the state was once the scene of a vast lake covering within the present state of North Dakota an area of 6,250 square miles, besides an approximately equal area in Canada. The area chosen for this investigation and described in this paper is so situated that the soils formed (a) by the deposit of sediment on the old lake bottom (b) those modified by the action of waves and currents along shore and (c) those of the higher land beyond the limits of the area covered by the lake, are represented.

History of Settlement. — North Dakota is one of the younger in the sisterhood of states, and this portion of the state has been set

tled only a very few years. Five years ago there was scarcely a shack outside of the city of Minot, and no roads were to be seen except those old Indian trails leading from far away towns to some trading station.

When the people of the United States and of other countries began to learn of the opportunities of the poor man in this region there was a grand rush to secure desirable farms. Many settlers had little idea of the labor and hardship that must be exercised if they desired to be successful.

The homesteader builded his 6x10 "shack" and began his existence on the prairie. According to law the homesteader must make a certain amount of improvement upon the land or he would be liable to have his claim contested.

Generally a few acres of sod were broken and a little flax seed sown. As all implements and horses were expensive, the first year's work was frequently not well done, most desiring to fulfill the law as easily as possible. As a rule the "breaking" was not more than two inches deep where it should have been at least five inches. As the country was subject to drouth, these methods were not successful.

Farm machinery has always been expensive and the poor settler must get along with as little as possible. For these reasons the land was not well worked and the drouth had a much more serious effect than it otherwise would.

By these methods the moisture, which was scarcely ever plentiful, was quickly evaporated. The crops then suffered.

Flax was usually the first crop to be sowed, as it brought the largest financial returns for the least amount of work. Of all crops flax injures the land most, and when sowed successively for several years the land is materially impaired.

By these methods and the fact that the soil is somewhat sandy, people were led to believe that agricultural pursuits could not be successfully carried on, as year after year the crops were injured by drouth.

As more settlers came and learned by experience, methods were improved. It was found that by breaking and plowing to greater depths there would be less danger of crop failure. Gradually, as the settlers became more well-to-do, they were able to have a better class of machinery and spent more time working the land before

crops were sown. However, even at present, many do not see the value of a thorough cultivation of the soil.

As the land is worked more thoroughly and more is broken up there is much less fear of drouth, although the annual precipitation is practically the same.

Agricultural development has been very rapid, and land that was formerly considered worthless now produces good crops. This is due to a large extent to the improved methods of farming.

Climate. — The growing season in North Dakota is short. The ground is generally frozen until some time in April. Frequently it is considerably later before seeding can be done. The crops ripen in August generally. Frosts may be looked for in September. The ground freezes so that fall plowing ceases usually early in November. Severe storms have been known to occur in September, though not commonly. The winters are cold, but usually the weather is steady and not subject to extreme fluctuations, so that the atmosphere is healthful and invigorating. Winter usually sets in in November, and the ground often remains frozen until April.

When a heavy snowfall occurs in the early winter the farms are not materially injured by the cold. The snow is very dry, and as it is usually accompanied with wind it is packed into drifts hard enough to bear the weight of a horse. On the general level of the prairie there is not usually a heavy body of snow, but houses have been nearly covered by the piling drifts. The temperature frequently stands from —20 degrees to —30 degrees F., and —40 degrees has been known, though such extreme cold is not common.

Physiography. — The surface features of North Dakota, except that portion west of the Missouri river, have been derived from glacial activities. The Mouse river winds its course through the northern part of the state. It enters the state at about 102 degrees west longitude, and forms an ox-bow which encloses about 6,250 square miles of area. This flat or basin was once covered by an immense body of water known as Glacial Lake Souris.

The area surveyed and described in this paper is located in part on the old lake bottom and in part outside the territory covered by the lake. Townships 156-82 and 156-83 were mapped with regard to the general character of the land, its agricultural value and types of soil as determined by examination of texture and fertility.

The Mouse river cuts across the southwestern corner of 156-83, but the river bed is not included in the area surveyed. Egg coulee, one of the largest channels in the region, extends through the northeast corner of 156-82. The area is cut by many coulees and glacial channels. Morainic hills and "pots and kettles" and fairly level prairie are also found in the area.

The altitude of the area is from 1,600 to 1,700 feet above sea level. In the eastern part of the area is a broad expanse of level or slightly undulating prairie which was formerly a portion of the bed of Lake Souris. The shore-line through the area extends from the southwest corner of 156-82 in a direction somewhat west of north through 156-83.

West of the shore-line the surface is more hilly, being morainic in origin and character. The hills are rough and stones occur in large numbers upon the crests of the hills. Between the hills are many "pots and kettles" or depressions which have such a heavy subsoil that water is held in some of them continuously.

East of the shore-line of the old lake the surface is more level, and is therefore better farming land. In the northeastern portion of 156-82 the surface is broken by many small hills. Between these are many small and shallow depressions. These hills were originally morainic hills, but owing to the action of the lake water they have been worn down and appear smaller and more regular than those in the western part of the area.

Many channels or coulees occur zigzagging across the area in various directions. These are generally deep and narrow. About the heads of these coulees is often a flat fan-shaped area. A low area may have a general slope from all sides toward one place which appears to be the head of the coulee. The channel immediately becomes deep and the banks serrated by many cuts and irregularities.

The coulees in the western portion drain into the Mouse river, but those of the east and south discharge into the locality of 156-80 and seem to disappear. These latter have a more abrupt beginning than those of the west. Without any warning a channel is observed to have a zigzag course across the country. These channels were probably made by glacial waters. They have contained much more water in ages past than at present. Only in the spring is there water at all, and then no perceptible erosion occurs on their bot-

toms. Many beds of gravel and sand are found along these channels. These were undoubtedly deposited by swiftly flowing water. A large portion of the bottom of Egg coulee in the northeast portion of 156-82 is heavy gravel.

Terraces or "benches" are of frequent occurrence on the banks of the larger coulees. These are generally of the sandy or gravelly character.

The hills in the southwestern portion of 156-83 are a part of a terminal moraine. The large stones and the general character of the hills indicate glacial origin.

Ward Silt Loam. — The soil type that covers the largest portion of the area will be termed, for convenience, Ward silt loam. The soil is from ten to twelve inches in depth. It is of reddish-brown or brown color and is a fine, sandy loam. It sometimes contains a very small amount of gravel, generally of limestone. The subsoil is usually of two or three strata. A stratum of sandy loam will be encountered and a stratum of silty material which contains scarcely any grit. It is probably derived from a limestone formation. Below there is a stratum of heavy, tenacious loam. This is variable in color. Frequently there are mottled streaks of red and gray in a brown loam. Sometimes large amounts of gypsum are encountered. This loam continues to a considerable depth.

The type covers the central and western portions of 156-82 and the northern half of 156-83. Much the same material is found in the soil of another type, that of the low hills. The Ward silt loam covers an area of gently rolling country, which contains many "pans," or shallow depressions of a few square rods in area. These "pans" are not generally cultivated, as water sometimes stands in them years at a time. Luxuriant grasses, which grow in these, make excellent stock food.

Although coulees in the form of deep channels occur upon the type, it is not drained to more than a slight extent. Frequently there are sloughs and "pans" which contain water all summer. The coulees do not drain the land for more than a few rods from their channels.

This type was formed by the waters of Lake Souris. Originally this was all morainic or hilly country. The action of the water has leveled the surface and left this soil.

A large variety of crops may be grown on this type. Wheat and flax are grown most extensively. Barley, oats and spelt are raised to considerable extent for stock fodder. Flax is usually sown upon fresh "breaking." This crop many times realizes a larger profit for less work than wheat, but has been found to be much more exhausting to the land.

This type is well adapted to raising truck products. Whenever truck products are planted, the improvement in the small grains in the following years is very noticeable. Trucking is a sure method of killing weeds. By trucking the land every few years the weeds are kept down, the land is benefitted and a fair profit is realized at the same time.

The yield of wheat is generally from fifteen to twenty-five bushels per acre, of flax from ten to fifteen bushels, of oats from twenty-five to forty bushels. On exceptionally good seasons forty to fifty bushels of wheat are raised and twenty to twenty-five bushels of flax. From sixty to seventy bushels of oats have been raised on a wet season.

Ward Sandy Loam. — In the southern part of 156-82 is a type of soil which will be called Ward sandy loam. This type covers only a few square miles, being found in the southern tier of sections of this township. The soil is about twelve inches deep. It is reddish-brown sandy loam and is usually very fine. There are frequently a few small pebbles. The subsoil contains less sand than the soil, and is tenacious and heavy. It is of brown color, containing mottled streaks of red (Fe) and gray (Ca Co 3). Quite large amounts of gypsum are also in evidence. The surface of this type is slightly undulating. There are few stones or bowlders.

There is very little drainage. The surface slopes towards the coulees for only a few rods from their banks.

This type is only a variation of the last discussed and might be classed with it. It was formed by the deposits of Lake Souris at the same time that the before mentioned hills were worn down.

The crops on this type are much the same as those upon the one last considered. The subsoil is somewhat heavier than that of the previous type and will, therefore, hold more water. This makes the crops show up somewhat better upon this type than upon the others. There is seldom too much rain during the growing season and so the land that will hold moisture is in greater demand. The

price of this land is appreciably higher than the most of that included under the last preceding type.

Morainic Sandy Loam.—The type which may conveniently be called morainic sandy loam is located in the northeastern half of 156-82. This portion of the area embraces the remains of a moraine that has been leveled to its present form by the action of the waters of Lake Souris. The morainic hills have not been worn to a level prairie but have been left in the form of small hills or knolls with depressions between them.

The type might be mapped as two separate types; one embracing the small hills and the other the depressions. The soil and subsoil of the hills differ from those of the depressions. However, it would be a difficult matter to illustrate the types, as the separate hills and depressions are of such small area. Each hill contains scarcely eight acres and the most of the depressions are even smaller.

Upon the high land the soil is from four to eight inches in depth. It is brownish sandy or gravelly loam. The subsoil is sandy, gravelly or stony loam.

In the low land between the hills the soil is from eight to ten inches in depth. It is of a heavy character, being sticky when wet, and is quite tenacious. The subsoil is still heavier, being silt loam, and is also very tenacious. It is of a brownish color. It contains some streaks of mottled red and gray.

The surface of this type is very different from that of any other. Small hills and knobs are alternated with low, hard "pans" and even "pots and kettles." There are no large areas of either low land or high land.

The type as a whole has no drainage except Egg coulee, which drains only a few rods from its channel. The water as it falls upon the higher lands immediately gathers in the clay bottomed "kettles" between the hills and here remains until it is removed by evaporation.

About one-fifth of the land of this area has been broken up and is at present under cultivation. The crops are principally flax and wheat. Unless there is an abundance of rain the crops are likely to be light. The uplands are too dry and gravelly to be advantageously cultivated and the low lands are too wet and heavy. Only a small portion is left for cultivation and only in limited areas. Wild grass grows luxuriantly in the low, wet depressions. If these bot-

toms dry out sufficiently the grass is cut for winter fodder. This type is not well adapted to farming. Grazing is best adapted to this area.

Morainic Loam. — The morainic hills in the southwestern portion of 156-83 constitute a type of soil very different from any previous type. This area is entirely out of the lake bottom. The hills stand up rough and rugged as left by the ice. The type consists of soils of different characters; the soils on the hills differ widely from those of the depressions. This type might be divided into two types. It would be difficult to map the hills as a separate type from the depressions as each occurs only in small areas. The character of the soil on the hills and in the depressions is so different that each would form a type of itself if correctly mapped.

The soil on the upland is only from two to four inches in depth. It is gravelly or stony loam. The subsoil is gravelly or sandy. In some places the hill tops are so stony and gravelly that little vegetation can sustain itself.

The sides of the hills vary; in some cases the soil and subsoil are heavier and considerable vegetation appears, while in other places the land is almost barren. The soil on these hillsides varies from coarse to fine sandy loam.

In the hollows or "pots and kettles" the soil is 14 to 18 inches in depth. It is generally heavy loam containing large amounts of decayed vegetable matter. It is usually of black or dark brown color. The subsoil is of much the same texture, though often somewhat more sandy. The soil is always wet and sticky and the subsoil is very tenacious.

This type is typical of a morainic country. The hills are from 30 to 60 feet above the bottoms. On some of the hills the bowlders are so numerous that one may walk across without touching the ground.

There is no drainage except as the water runs from the hills to the bottoms between. There are many swamps and even small lakes which have no outlets.

This moraine is only one of many in North Dakota. Its course may be traced from the vicinity of Minot into Canada, and far southward across the state.

Only a very small portion of this land is being farmed. This is due to the roughness of the surface and the non-fertility of the

soil. The best occupation to be carried on is grazing. There are some very successful ranches at the present time. Buffalo grass grows to some extent upon the hills and grasses of many varieties grow in the sloughs.

Ward Gravelly Loam. — Along the coulees and channels is found a considerable amount of gravel which for convenience will be called Ward gravelly loam.

The soil of this type is from 4 to 6 inches in depth. It is of brownish color and owing to its looseness of texture is not very fertile. Generally sand and gravel are apparent. The subsoil is somewhat heavier but still contains considerable gravel. In some localities almost pure gravel is found to a considerable depth. The gravel found in the channel of Egg coulee differs somewhat from the others. The gravel stones are larger and are more numerous. Some are as large as the fist.

These gravels are deposits from glacial streams. Terraces occur along most of the large channels. In every case the gravel has been deposited by the waters of ancient glacial streams. The waters that flow in the channels at present scarcely leave a trace of erosion from year to year. Small areas of gravel are found along the coulees which are too small to be shown on the map.

This type occurs in the southwestern part of 156-82 and also in the channel of Egg coulee in the northeastern part of 156-82. The whole area of Ward gravelly loam does not cover more than a few sections.

The vegetation on this type is not heavy. Where crops have been seeded they are not usually successful unless there is plenty of rainfall. The grass is small and wiry and weeds are plentiful.

As yet no crop seems to have been applied that was well adapted to the type. Grazing is the most profitable use to which the land has thus far been put.

Ward Clay Loam.—The low, heavy land of this area has a type of soil somewhat different from any other land in the district. There are two kinds of low land which may be taken up separately. There are broad channels which extend entirely across the area. There are also many small areas of low land which have much the same type of soil.

The broad flats are old glacial channels. One of these contains a part of sections 2, 3, 10, 11, 12, 13, 14, 15, 22, 23, 24, 25 and

26 of township 156, range 83. This divides, and one branch joins another flat or channel in township 156, range 82. This one is smaller, partially containing sections 4, 5, 8, 17, 18, 19, 20, 29, 30, 31 and 32. These channels, in such cases, have high bluffs bordering, while in some places there is no definite division between the channel and the level prairie.

The small areas, referred to, are dried up sloughs or lakes. These usually contain only a few acres of land. They are found in sections 3, 9, and 22-23, of township 156, range 82. In township 156, range 83, they are found in sections 29 and 28-27-34. One of the channels has its beginning in township 157, range 83. The head is much the shape of a fan. It spreads out over five or six square miles. In this particular channel there is a coulee, but the coulee is not of the same formation as the larger channel. There is some water in the lowest part, but is entirely stagnant.

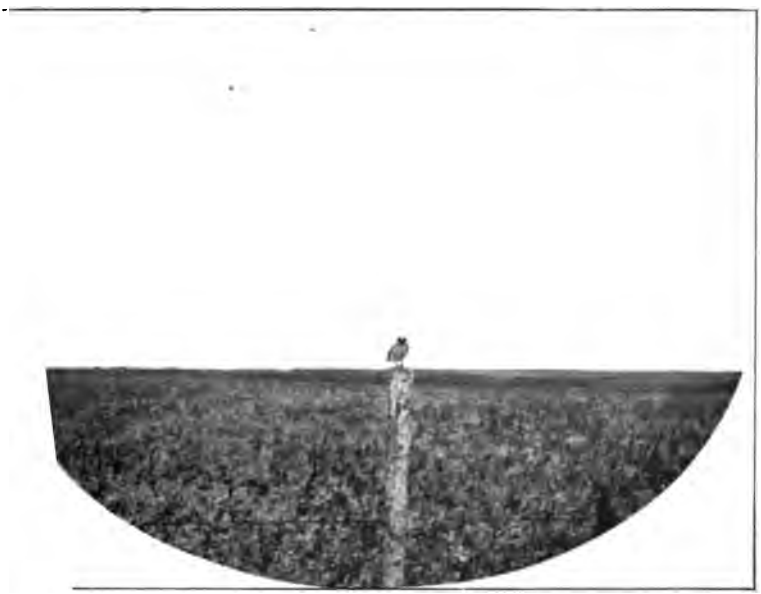
The soil in these channels and flats is from 10 to 18 inches in depth. It is of a black or dark brown color. It contains large amounts of decayed vegetable matter which makes the soil very fertile. The soil is heavy and tenacious and usually contains considerable moisture.

The subsoil is a large, heavy loam of very fine sandy loam. It is f grayish-brown color and sometimes contains small amounts of iottled red. In the channels the subsoil seems to be in strata, hile in the open flats the subsoil is usually uniform. Small eleations of gravel occur in the channels, formed by ancient glacial aters. These have been discussed under Ward gravelly loam. a few cases there are large morainic deposits in the channels rming quite large hills. (See sections 10-15, township 156, range .) These are gravelly or stony on the surface.

The low-land flats, i. e., the dried up sloughs or small lake botms, are not generally good farming land. The soil in these is om 14 to 18 inches in depth. It is heavy, black loam containing uch decayed vegetable matter. The soil is fertile but is generally vered with water until too late in the season or is baked too hard be tillable. The sod when turned appears hard and tough. ne subsoil is heavier than the soil. It is usually grayish-brown ith some streaks of red and white.

These pans have a waterproof bottom. Water once in them n only get out by evaporation. These low tracts are of small

Morainic Lake Filling with Vegetable Matter. (Muskrat house in center.)



One of the First Occupants of the Soil.

A very small portion of the land is held by speculators. This is either rented or lies idle. Very few farms are rented, and where so they are generally poorly farmed. Any good, progressive farmer will not rent but will own a farm of his own.

The problem of hired labor is one of the most important. Men come into the state for the summer's work and then out again. Their only desire is to make as much money as possible with little work. Frequently these men are poor farmers and are therefore poor laborers.

Wages are high compared with that of the class of laborers and work of other states. A monthly wage of $30 is usually paid for five or seven months, beginning with April. Day laborers in harvest time receive from $2 to $3 per day. The laboring class is small in numbers and it is frequently a very difficult matter to obtain sufficient laborers to carry on the harvest.

The Great Northern railroad and the M., St. P. & S. S. M. railroad pass through the city of Minot. Each furnishes fair freight service. Large elevators are located on each railroad and grain is hauled to them in large quantities. As nearly as may be estimated the average price of hauling grain on the public roads is ½ cent per bushel per mile.

The roads are usually prairie trails, and are only graded where the worst sloughs are encountered. On account of the sandy texture of the soil these roads are seldom muddy except in the low lands.

The grain markets are generally good. Wheat and flax are sold at a fair discount from prices in St. Paul and Minneapolis. Only a small portion of the grain is shipped by the farmers, but is sent through the elevator companies.

THE SURFACE FORMATIONS OF SOUTHEASTERN NORTH DAKOTA.

BY DANIEL E. WILLARD.

In common with most of the northern states, nearly all of North Dakota and Minnesota is covered with a mantle of drift due to the presence of the great ice sheet. Eastern North Dakota was affected directly by the ice in a manner much like that of other parts of North America over which the ice passed. The area is deeply mantled with drift or till. In addition to this a belt including approximately the eastern tier of counties of the state is covered with a deposit arising from the melting of the great ice sheet known as lacustrine silt. Streams upon the adjacent land surfaces were kept at flood by the waters from the melting ice, and large volumes of sediments were swept into and down these streams. Sandy beaches, washed by the waves, became the assorting grounds of the coarser sediments conveyed into the lake waters, and off-shore currents became the builders of sand bars. The finest rock flour or silt was that which came to rest in the still waters of the lake far from shore. The Sheyenne delta, a vast mass of sand, gravel and shale transported from the margin of the melting ice sheet or eroded from the plain over which the waters flowed, is an illustration of the great work done by the flood waters from the melting ice. The large amount of shale in the delta deposits and the depth to which the ancient glacial river eroded its bed below the drift mantle into the underlying shales outside the Red River valley indicate the vast work of erosion and transportation accomplished by the waters of the melting ice sheet.

The region immediately west of the Red River valley was not covered by the waters of Lake Agassiz. This is a region of till or bowlder clay of the same character as that lying beneath the stratified lacustrine sediments of the Red River valley. The bowlder clay is composed in part of materials transported for greater or less distances by the ice, but is mainly the pulverized materials plowed up along the course of the moving ice, as is shown by the similarity of the drift clay to the stratified clay-shale below revealed in the records of well borings.

The surface deposits of southeastern North Dakota are drift materials, those in the Red River valley being modified by the action of

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New Era Road, Near Fowler Farm, Cass County.

Lone Poplar Trees on Sandy Beach of Lake Agassiz.

the waters of Lake Agassiz. Below the modified lake deposits is the till, similar in character to that of the rolling prairie beyond the area covered by the lake. The total depth of the drift, as determined from well borings and from the deep valley of the Sheyenne, is from forty to sixty feet upon the rolling prairie in the western portion of the area now considered to 200 to 250 feet in the axial portion of the Red River valley. The depth of the drift varies considerably owing to the uneven surface of the preglacial landscape. Four types of drift deposits occur in this portion of North Dakota. These are (a) the fine sediments deposited in the deep waters of the lake and known as lacustrine silt; (b) the reworked drift represented in the beach ridges and other shore deposits; (c) the delta deposit made by the Sheyenne river; and (d) the rolling prairie with low morainic hills.

Lacustrine Silt.—The lacustrine silt deposits overlying the till extend westward of Casselton and embrace the region southward beyond Wahpeton and northward beyond Grand Forks. Its greatest thickness is as much as sixty feet and it is commonly as much as thirty to fifty feet. This deposit consists of the finest particles of rock brought into the lake by streams or washed from the wall of ice which formed the northern shore of the lake. This finest rock flour from the great continental ice mill was laid down in perfectly stratified layers in the quiet waters of the lake, the upper layers being blackened and enriched by accumulations of carbonaceous matter from the decomposition of plants and animals which found a habitat in its cold waters and in the shallow marshes which succeeded the disappearance of the lake. These blackened marshes in turn became the dry meadows of prehistoric days.

The Sheyenne Delta.—The great delta plain of the glacial Sheyenne river covered the southern one-third of the Casselton quadrangle and the southwestern corner of the Fargo quadrangle. This is a sandy plain representing the coarser sedimentary deposits of this once great river. The total area of the delta is placed by Upham at 800 square miles, and is estimated by him to have an average depth of forty feet. The northern and eastern front of the delta in Cass and Richland counties rises quite abruptly sixty to seventy feet from the almost perfectly level surface of the lacustrine sediments of the old lake bottom beyond the limits of the delta. The deposit is one of fine sand and fragments of shale with a scant admixture of clay, so that the texture is in general quite loose. The surface of the plain

Wind Blown Sand Encroaching Upon the Valley North of Walcott.

Old Baldy, a Large Sand Dune, Richland County.

: clayey character in the delta itself, or by the hard, impervious vhich forms the floor beneath the delta deposits. The ready olation of the waters and the impervious beds of clay make the rrence of springs common along the delta front and in the deep nels of the rivers. On the lower plain of the lake bottom bel the delta the hydrostatic pressure of the surface waters peneng the ground upon the higher land of the delta causes the waable to rise to the surface of the ground, and considerable areas endered quaking, boggy marshes.

ie northeast front of the delta, about midway between the Sheyand Maple rivers, near the village of Leonard, is intersected by ral deep coulees which have been formed by the action of springs ting out from the delta. These may fittingly be called "travelsprings," since they travel backward into the plateau as a reof the action of their own waters in removing the erodable mals out of which they emerge. The same mode of "traveling" served in the springs which head the coulees along the valleys e Sheyenne and Maple rivers. The spring half a mile west of ard village has eroded a gorge two miles in length with a maxidepth of seventy feet. Other coulees in the vicinity are half le to nearly two miles in length, formed in the same manner. springs occur in the banks of the Sheyenne river along its e outside the Red River valley for 150 miles in Ransom, es, Griggs, Nelson and Eddy counties, where the valley of the is cut deeply into the soft cretaceous shales which underlie the

aches of Lake Agassiz.----West of Casselton is a belt about iles in width extending from the northern edge of the Sheydelta northward with varying width beyond the limits of the This is a tract having the characteristic topography of a -washed shore of a receding sea. The western side of this a marks the highest point reached by the waters of Lake Agas-

this tract the 1,100-foot and 1,000-foot contours are sepaby intervals of only about three miles, whereas the 900-foot ur is about forty miles to the eastward of the 1,000-foot connear the Red River of the North.

e slope between the higher contours represents the eastern face Manitoba escarpment. The region was covered by the waters

of Lake Agassiz during its highest stages, and was relieved of the covering of water as the lake receded. Well marked gravelly and sandy ridges traverse the area in a generally north-south direction. These are the beach ridges formed by the action of the waves and currents of the lake upon the shore. The ridges are composed of whitish sand with a little clay, and gravelly places are frequent. Sand for building purposes and gravel for road construction are obtained from pits. The eastern slope, or front, of the beaches is usually more steep and higher than the western, or back, side, and a marshy tract often lies back of a ridge, drainage to the lower levels to the east being prevented by the ridges which act as barriers. The area is one of reworked drift and lacustrine deposits, some places where the configuration of the shore was not such as to cause breakers to accumulate sand and gravel in ridges being covered with true lacustrine deposits.

The highest wave-marked ridge is known as the Herman beach, and this represents the height of the water at the time of its greatest extent. The recession of the lake was not gradual, but was by stages of intermittent recession and pause. The next lower stage than the Herman was the Norcross, represented on this area by a ridge about four miles in extent lying along the boundary line of Eldred and Walburg townships, and another fragment about two miles in length in Wheatland township. Fragments of beach ridges representing the upper and lower Tintah stages of the lake occur along generally parallel lines at intervals. North of Leonard village the Tintah shore is marked by an escarpment eroded by the waves in the front of the delta. That the Tintah beaches represent two stages or levels of the lake is shown by the fact that the two nearly parallel lines connecting fragments of well defined ridges are separated by a vertical interval of about twenty feet.

The most conspicuous beach on this area, unless it be the Herman, which is conspicuous because it delimits the lake area from the rolling drift topography to the westward, is the Campbell, which extends from the point where the Maple valley debouches upon the level plain of the lacustrine sediments in a generally northward direction. Frequent gravel- and sand-pits occur along the course of this beach. It is in part a well defined ridge, rising with a sharp slope on the east or lakeward side, and falling a less amount on the west or landward side, and in part an eroded cliff or escarpment

The Herman Beach, Near Absaraka.

ological Excursion of a Class from Agricultural College to Herman Beach.

The Campbell Beach at Wheatland.

Banks of Sheyenne River West of Fargo.

:ned in the drift clay or till by the cutting action of the waves of lake. This beach is a conspicuous landscape feature and marks pr n·ipal boun lary between the level area of the acustrine sedi-:nts and the reworked drift which forms the "bench" land border-the old lake bottom.

The McCauleyville beach, which marks the lowest stage of the e while its waters were drained southward by the river Warren very feebly developed in this locality. It is represented by two gments not exceeding a mile each in length in Walburg and Gill vnships respectively. This beach is elsewhere a conspicuously de-o; ed ridge bearing sand and gravel and traceable continuously for .ny miles.

The beaches just described as occurring on the western side of the .e, also occur on the east side of the valley, the several beaches resenting the higher stages of the lake occurring on a gentle slope ·ing westward between Hawley and Glyndon, Minnesota. Bowl-·s occur in great abundance on this slope. Some of these bowl-·s are of immense size, and their distribution along the higher re lines of the lake suggests that they may have been carried by t ting blocks of ice and stranded upon the sand bars off shore.

The Unmodified Drift.—West of Magnolia station and Sheldon land was not covered by the waters of Lake Agassiz, and the ·ion is therefore beyond the limits of what is known as the Red ·er valley. This is an area of rolling and undulating drift, the ography being that of the type which characterizes much of the tern half of the state of North Dakota west of the area of the ient lake bottom. The 1,100-foot contour coincides in a general · with the highest line marked by the action of the waves of the .·. Succeeding contour lines marking twenty feet of vertical dis-.·e follow rapidly toward the west, two contour lines crossing ıy of the sections, these lines running nearly parallel with each ·r and with the Herman shore line. As has been before noted, ·e is a fall of only 160 feet in about forty miles from the Camp-shore line eastward to the Red River of the North.

Morainic Islands and Beaches.—An embayment of the ancient e Agassiz existed in the southwestern part of what is now Cass nty, nearly midway between Magnolia and Sheldon. North of embayment is a hill about two miles in length and averaging ut one-third of a mile in width, which was an island in Lake

Agassiz during a short time at its highest stage. Southward from this island a similar hill having a width from north to south of two miles projected as a promontory or headland into the ancient lake; a neck of land about a mile in width connected this promontory with the general highland a mile west. These hills are typical morainic hills, being composed of hard bowlder clay with occasional sandy or gravelly layers, and bowlders of granite, quartzite and limestone.

Extending for a distance of three miles in a north and south direction between the eastern extremities of these highlands is a conspicuous gravelly beach-ridge. This ridge marks the line of the "breakers" between these two highlands at the time of the second Herman stage of the lake. Another segment of the second Herman beach about two and one-half miles in length lies two miles north of the northern extremity of the island just described, and half a mile east and twenty feet lower than the highest Herman shore. Five miles further north a feebly developed shore line representing the second Herman stage lies at about the same distance east of the upper beach and separated by about the same vertical interval..

Lagoons Back of the Beaches.—Thus the island referred to was an island only for a short time, viz., the period, whatever its absolute length, during which the lake stood at the level of the upper Herman beach. During the second or lower Herman stage of the lake the region embraced in the embayment lying west of the island was an overwash slough or lagoon, the waters which were driven by the winds across the "breaker" line forming a broad pond or shallow lake back of the beach ridge.

In a similar manner lagoons or sloughs were formed back of the high ridges formed at different stages of the lake. It is thus that sandy marshes, which occur frequently back of the sandy or gravelly beaches, are explained. The breaking of the waves where the lower part of the rolling mass of water was retarded by the friction of the bottom caused the coarser gravel and sand to be thrown down in more or less uniform layers, forming the beach ridges which have been described, the finer sand and silt being carried over the crest of the bar, where these settled in the still water of the lagoon. The soil of these lagoon tracts is thus frequently not only composed largely of fine sand and silt, but the soil is often impregnated with alkali derived from the continued evaporation of the lake water during the existence of the lake, and from the accumulation from evaporation since the disappearance of the lake.

E GEOLOGY OF THE SOILS OF SOUTHEASTERN NORTH DAKOTA.

By Daniel E. Willard.

.acustrine Silt.—Probably there are few regions in the world ich exceed in fertility of the soil that of the Red River valley. e soil consists of the finest of rock flour ground and pulverized by great ice sheet and borne into Lake Agassiz by the inflowing :ams. Only the very finest of the assorted sediments thus dis- uted by the waves and currents of the lake were deposited in the ;er portions of the lake, as the coarser materials were thrown 'n when the inflowing streams were slackened by the still water. 'y the finest could remain in suspension in the water till they came 'est in the deep water of the central lake. This finest powder 'ock is known as lacustrine silt, and when wet and compacted to- 1er has much the character of clay, differing from clay in that it :ains fine sand, fine powder of limestone, and carbonaceous mat- and does not have the coherent properties of clay.

'Gumbo" Areas.—Areas varying in extent from a few square ls to a few square miles of very compact and heavy soil occur n these level bottoms through which water percolates very slowly, when dried by the intense heat of summer forms hard blocks, surface cracking into characteristic geometrically formed prisms. 'se are known as "gumbo spots." This soil is very sticky when and hence not readily worked in farming pursuits. Owing to its lency to bake into hard blocks and its impermeability to water, ch renders drainage difficult and frequently causes accumulation .lkaline salts, the gumbo areas are not as desirable lands for farm- purposes.

'iver Alluvium.—Bordering the rivers upon the plain of the Red er valley, river alluvium forms a mantle which overlies the orig- fine lake sediments, thinning from a thickness of several feet at river banks to an attenuated sheet at some distance from the am channels. This material is the fine overflow deposit from rivers and is slightly more coarse in texture than the lacustrine mentary deposits. These deposits are coarser nearer the river ks because the heavier particles are the first to be deposited. ross section of the alluvial banks, therefore, would show a wedge

Ash Trees, Five Years Old from Seed, Agricultural College Farm.

Group of Cattle Grazing on Ranch near Sheldon in Cass County.

Old Farm Machinery Buried by Sand Thrown Out of Budke Artesian Well, South of Wheatland.

Group of Cattle Grazing on Ranch near Sheldon in Cass County.

Old Farm Machinery Buried by Sand Thrown Out of Budke Artesian Well, South of Wheatland.

compact substance offering a high resistance to the percolation of waters. So-called surface wells are often not surface wells at all, when by surface wells is meant such as derive their water supply from percolation or seepage from the soil in the immediate vicinity of the well, but are obtained by penetrating a layer of nearly impervious clay below which a water-bearing vein of gravel or sand is struck, the clay acting as a restraining wall to hold the water.

The Water Table.—The permanent water table is high in this region, due principally to two causes. These are that the deeper subsoil or till is nearly impervious to water, thus preventing underdrainage, and the level character of the land by reason of which a very slow progress of the soil water toward the streams results. The soil and subsoil are sufficiently porous to allow a very slow percolation of the water, and the deeper clay acts as a vast dish holding the water.

Alkali in the Soil.—The question of alkali in the soil is one of great importance. In some localities the alkaline salts in the soil become a hindrance to agriculture. The percentage of salts in the soil is found by analysis to increase with the depth. Not infrequently shallow surface wells furnish abundant supplies of water. This is sometimes of excellent quality, but sometimes it is so highly impregnated with salts as to render the water unfit for drinking or even for the use of stock or for steam boilers. The use of water therefore from surface wells is not general.

As the surface waters evaporate and deeper soil waters rise by capillarity, alkaline salts are brought to the surface and there, by rinsing from melting snow and spring rains these are removed to the streams wherever there is surface drainage. Lower places toward which surface drainage tends and from which there is no escape for the waters, become in time by the concentration from continued evaporation what are known as "alkali spots." "Gumbo spots" are often of this character, the subsoil being so compact that underdrainage is reduced to practically nil. The alkali becomes gradually more in amount and these places become unproductive as a result.

Because of the removal of the soil alkalies and other salts by the surface waters the waters of all the streams contain some amount of alkaline and other salts, and because there is alkali in all the soils and subsoils and also in the deeper till, all the well waters contain some greater or less amount of mineral impurities. The waters may

be soft and suitable for washing purposes and for drinking, still the are no pure waters. For the most part the amount of alkaline ar other salts in the deeper wells is not so great as to seriously interfer with the obtaining of supplies of reasonably pure and suitable wate for domestic and general agricultural purposes.

As all the soils and subsoils are of drift origin, it follows that th ultimate origin of the alkaline and other mineral substances was in the stratified rocks of the preglacial land surface. The salts are therefore those that were carried in the waters of the ancient Cretaceous seas, on the bottom of which these rocks were originally deposited as sediments.

While the alkalies in the soils are sometimes a detriment in the unwholesome effects upon the character of the waters for domestic uses, and sometimes also are present in so great a quantity as to render small areas of land unproductive, yet on the whole the alkaline and other mineral salts in the soil of this area add greatly to its productiveness as when present in not too great quantity they furnish necessary plant food, and add greatly to the fertility of the soil.

GEOLOGIC HISTORY OF EASTERN NORTH DAKOTA.

By Daniel E. Willard.

In but very few places in the eastern portion of North Dakota is there an exposure of the underlying stratified rocks. Our knowledge of the rock formations which form the floor underlying the drift, those rocks which were the surface formations before the invasion of the great ice sheet, is therefore derived largely from artificial borings. Deep wells have penetrated the hard granite on the Fargo quadrangle at 252, 255, 256, 266, 286, 295, 298 and 475 feet; and upon the Casselton quadrangle at 111, 150, 170 and 490 feet. The only formation of the sedimentary series which is passed through in these wells is a shale formation containing layers of sand, Cretaceous age. Thus there is no record preserved in the rocks of this area of the time represented by the Cambrian, Lower Siberian, Upper Silurian, Devonian, Carboniferous, Triassic and Jurassic eras.

The Cretaceous shales and sandstones rest unconformably upon the granite complex. The upper portion of the Cretaceous strata

Flowing Well and Stock Barn, Red River Valley. (This is what man builds on North Dakot soil after the days of pioneering have passed.)

After the Aborigines Came the Pioneers. (Sod House Southeast of Lisbon.)

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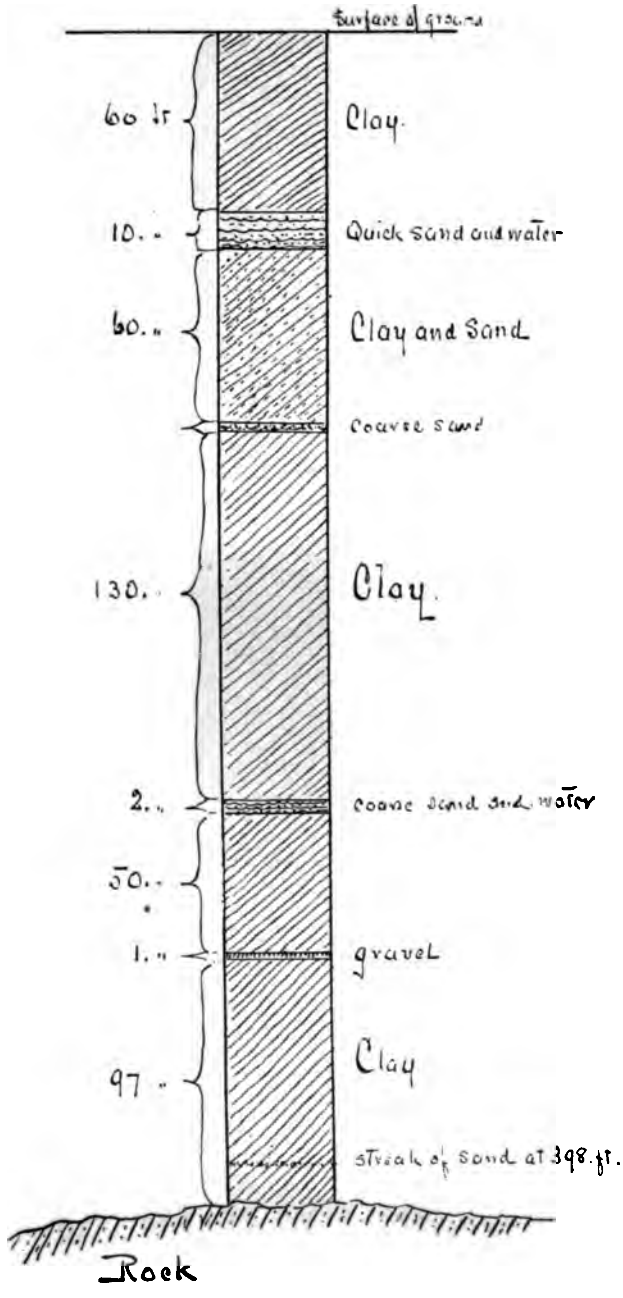
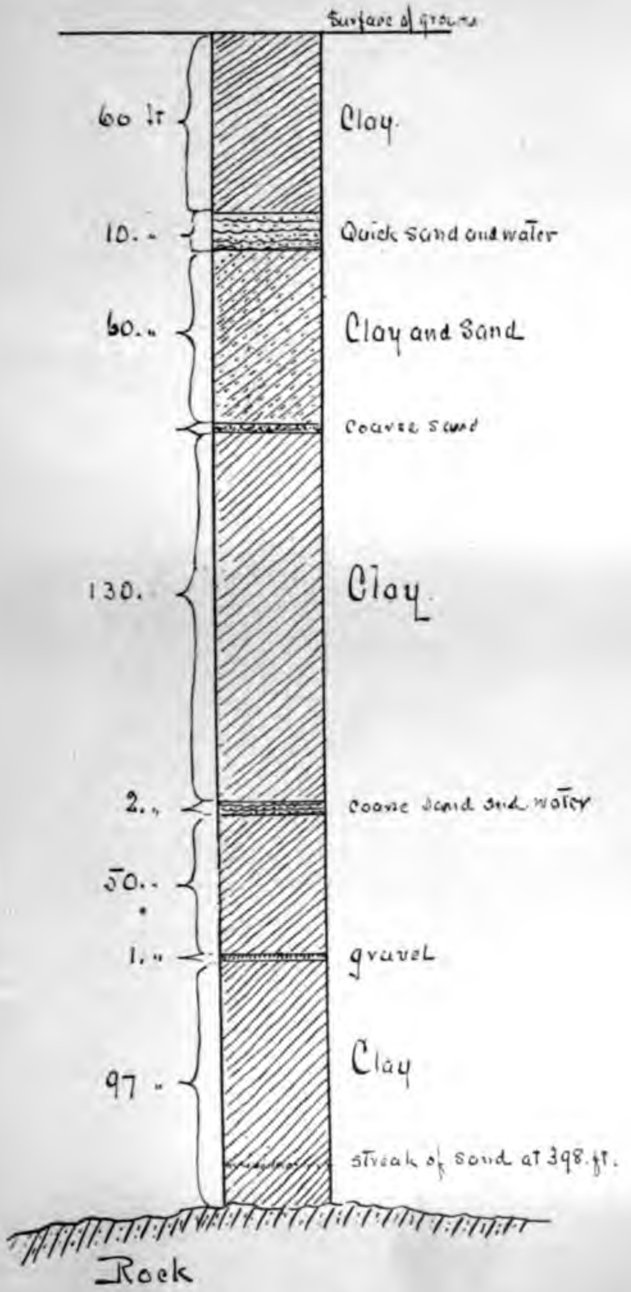


Well on Douglas Farm, Cass County.



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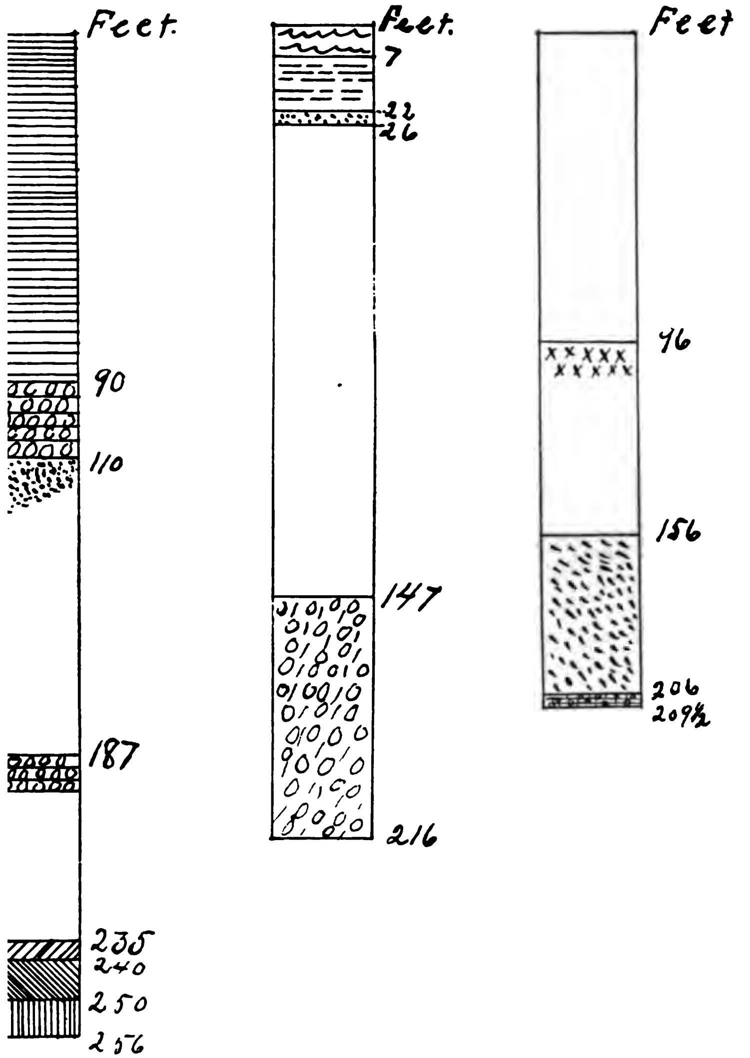
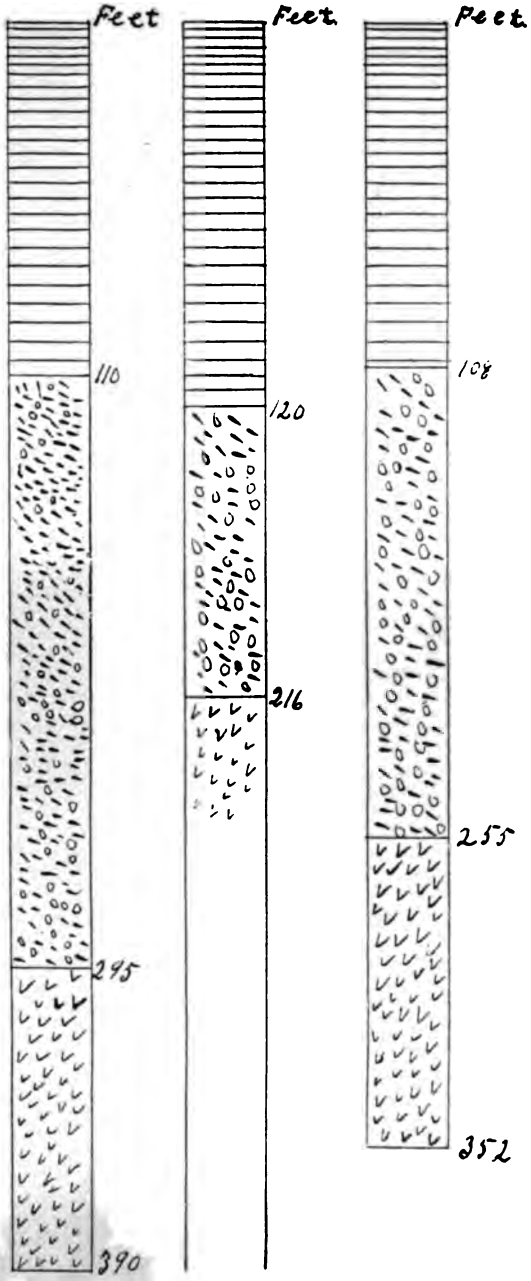
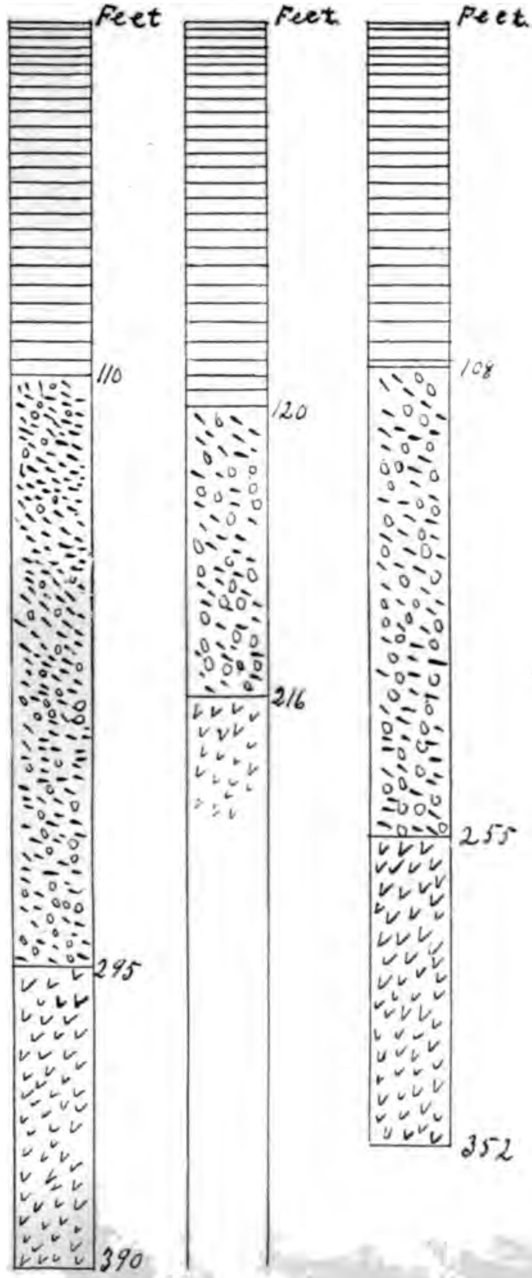


Well Sections, Fargo Quadrangle.



Well Sections, Sec. 36, Tp. 141, R. 48.



Well Sections, Sec. 36, Tp. 141, R. 48.

Near the point of debouchure of the Sheyenne valley into the Red River valley, about ten miles southeast of Lisbon, outcroppings of shale occur in the sides of the glacial Sheyenne valley which have been by Upham provisionally referred to the Benton. Also shale penetrated in deep borings at several points in the upper Red River valley have been provisionally referred to the Benton by the same authority. (U. S. G. S. Monograph XXV, p. 92, also chapter x.)

The "second clay" of drillers is encountered in the vicinity of Fargo at depths of less than 200 feet to 300 feet. Clays described by drillers as "light green," "decided green," and "white and chalky," and "putty-like" are reported at depths of 208 feet to 250 feet, and in the deep well at Moorhead at 370 feet. These clays in every case extend down to hard granite at 252 feet to 298 feet, and in the Moorhead deep well to 475 feet. In the last named granite was penetrated all the way to 1,901 feet.

In the vicinity of Casselton the "second clay" is struck at 200 feet to 300 feet, and deeper clays or "third clay," with layers of hard pan and gravel at 300 feet to 520 feet. White clay is reported from wells in the vicinity of Casselton at 292, 300 and 420 feet respectively, with hard granite below, and hard granite at 411, 450, 470 and 490 feet respectively. Flowing wells are not obtained in the vicinity of Fargo, the line of the eastern limit of the Dakota artesian basin being a few miles east of Casselton. However, deep wells yielding water from a fine white sand rock are common about Fargo, in which the water rises nearly to the surface of the ground. If these sands are provisionally assumed to be Dakota in age, and hence regarded as the eastern continuation of the Dakota artesian water bearing sands farther west, here immediately overlying the granite, it would then be natural to correlate the "second clay" of the Fargo and Casselton areas with the Benton shales farther west. Until fuller field records have been obtained upon the territory to the south and west, it seems of doubtful utility to attempt to definitely assert the age of the clay and sands underlying the drift and covering the granite bed rock of the upper portion of the Red River valley.

The Structure Section.— A structure section from western Minnesota across the Red River valley on the latitude of Fargo shows the granite bed rock immediately underlying the Cretaceous shales and sands, the former passing beneath the latter toward the west. The Cretaceous formations have a westward dip toward the great

synclinal basin in which the latest formations within the state of North Dakota were deposited as sediments in the great inland sea. The outcropping edges of the Cretaceous strata in the Manitoba escarpment represent post-Cretaceous erosion, by which the great preglacial Red River valley was formed as a trough across the eastern edge of the great syncline. The glacial deposits, till and lacustrine sediments, represent the later work of the glacial period, and the somewhat broken line marking the upper limit of the section represents the present land surface.

Over all the region included in this paper borings penetrate below the drift into Cretaceous shales and sands, and upon all except the western one-third of the area below these into hard granite. The lowest of these Cretaceous strata, and upon the eastern portion of the area, it may be the only one, is the Dakota formation. Farther west and beyond the Manitoba escarpment the Benton, Niobrara and Pierre shales are encountered in ascending order.

The occurrence of the Benton upon the floor of the Red River valley has been discussed elsewhere in this paper.

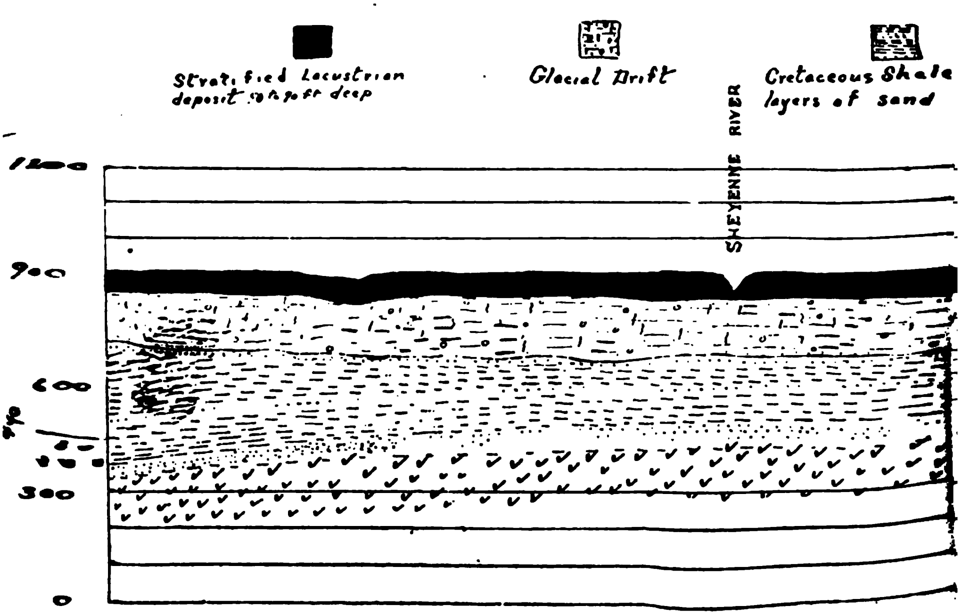
The deepest borings in the territory immediately west of the Red River valley do not penetrate below the Dakota sandstone, but it may be supposed that at some distance west successively older formations would be encountered at still greater depths, and finally the granite bed rock at the bottom and below all.

The occurrence of artesian wells which derive their water from a sandstone formation, over much of eastern North Dakota, is explained by the structure of the synclinal basin which extends westward from the region of the Red River of the North to the Rocky Mountains, and southward to the Black Hills. Flowing wells from the Dakota sandstone horizon are obtained at depths of 200 feet near the eastern limits of the artesian basin, at 100 to 500 feet upon the western portion of the Red River valley, at depths ranging from 650 feet to 800 feet twenty to thirty miles west of the Red River valley, and still farther west in the valley of the James river at 825 to 1,500 feet.

The western outcropping edges of the Dakota formation flank the eastern highlands of the Rocky Mountains, and the Black Hills, and it is from these regions that the water is supposed to be derived. Here the rains penetrate the porous sandy formation lying at the surface at altitudes from 1,000 to 6,000 feet above sea level, and trav-

erse the sandstone layers to the eastern portion of the syncline. At Jamestown and Devils Lake the water bearing formation is encountered at about sea level. The artesian water bearing horizon of the

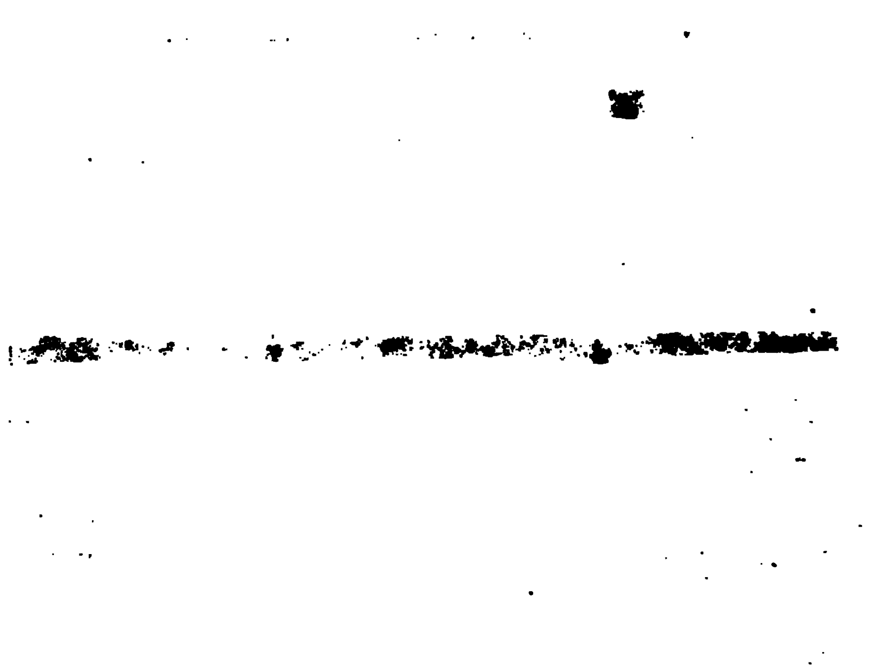
AGRICULTURAL COLLEGE SURVEY



from such wells shows that the effect of weathering, though no very accurate description of the unconformity between the old granite and the much later shale can be at present given, was very great.

The occurrence of white and green varicolored clay, from five to fifty feet in depth, and in the deep well at Moorhead 105 feet, overlying the hard granite, indicating a decomposed and much changed con nite, shows that the granite was long exposed to

synclinal basin in which the latest formations within the state of North Dakota were deposited as sediments in the great inland sea. The outcropping edges of the Cretaceous strata in the Manitoba



valley, and still farther west in the valley of the James river at 820 to 1,500 feet.

The western outcropping edges of the Dakota formation flank the eastern highlands of the Rocky Mountains, and the Black Hills, and it is from these regions that the water is supposed to be derived. Here the rains penetrate the porous sandy formation lying at the surface at altitudes from 1,000 to 6,000 feet above sea level, and trav-

erse the sandstone layers to the eastern portion of the syncline. At Jamestown and Devils Lake the water bearing formation is encountered at about sea level. The artesian water bearing horizon of the Dakota formation rises to about 700 feet above sea level upon the eastern side of the syncline.

The accompanying cross section of the Red River valley shows the structural relations as they would appear along the line of the Northern Pacific railway. This section shows the black lacustrine deposit of fine sediment to a maximum depth of sixty to seventy feet in the axial portion of the Red River valley, and thinning toward the western margin of the lake bottom. Below this occurs the bowlder clay or till to a depth of 150 to 200 feet. Then below follows the Cretaceous shales and sands, and these rest uncomformably upon the granite bed rock. The top of the shale is quite uneven, as is shown by the inequalities in the depths of borings for wells. At the top of the drift a layer of hard clay is often encountered, and below this water is generally obtained which rises often nearly to the surface of the ground. The hard-pan, as the layer of hard clay at the bottom of the drift is called by the drillers, was formed by the pressure of the moving ice, shoving its mighty mass over the surface of the landscape, together with the indurating processes of the water which forms a restraining crust above by the concentration of the salts from the clay above and from salts dissolved out of the rock layers through which the water has passed.

The granite bed rock is of unknown depth. Little is known of its character in this region, because few borings have been made which penetrate it, and it is nowhere exposed at the surface. It is so deeply buried, and because it does not seem likely ever to yield either water or valuable minerals in this locality, its particular character seems not likely to be soon explained. Its surface is shown to be somewhat uneven by the difference in depth at which it is struck in well borings. The decomposed character of the rock removed from such wells shows that the effect of weathering, though no very accurate description of the unconformity between the old granite and the much later shale can be at present given, was very great.

The occurrence of white and green varicolored clay, from five to fifty feet in depth, and in the deep well at Moorhead 105 feet, overlying the hard granite, indicating a decomposed and much changed condition of the granite, shows that the granite was long exposed to

the action of atmospheric agencies before the surmergence of the old land surface and the deposition of the Cretaceous sediments.

That the Cretaceous sediments overlying the granite were also laid down in a shallow sea is shown by thin beds of coal encountered in the sandstone formation which overlies the granite, and which has been referred to the Dakota.

THE WATER SUPPLY.

BY DANIEL E. WILLARD.

Dependence Upon Wells.—The southeastern portion of North Dakota is intersected by the Red River of the North and several tributaries, each entrenched in a well defined channel. The larger of these streams are never dry, and the smaller only during very dry seasons, but owing to the generally level topography of the region their currents become very sluggish during the summer, and the water, which receives organic matter from the banks along their courses, is therefore not suitable for household purposes without filtering and boiling. It is, however, used for stock by those farmers whose buildings are situated near the banks of the streams. The Red River of the North is the source of the general supply for the cities of Fargo and Moorhead for street sprinkling, lawns, fire protection and laundry purposes, not however for culinary or general domestic purposes. The supply from streams which is within practicable reach of the inhabitants of this portion of the state for any purpose is limited to the comparatively few who live near the banks of the larger streams. By far the greater number of the inhabitants are so situated that a water supply from any stream is impracticable, and the dependence is upon wells. The Red River of the North, with its principal tributaries, the Sheyenne, the Wild Rice and the Maple, are the only perennial streams, and but few coulees intersect the intervening lands. Outside the cities of Fargo and Moorhead probably fully nine-tenths of the population is dependent upon wells for a water supply for all purposes, while not more than one-tenth could without great labor and inconvenience obtain their farm water supply from streams.

Springs.—The occurrence of springs within the level bottom of the Red River valley is extremely rare. The water seeping under

Northern Pacific Bridge, Between Fargo and Moorhead, Showing Flood of 1897.

Island Park, Fargo. Showing Flood of 1897.

the heavy lacustrine clays from the regions along the borders of the valley are effectually held down by the impervious clay, so that what would otherwise break forth as springs is now held in confinement, furnishing water for the tubular and Pleistocene artesian wells, where the restraining clay is penetrated in drilling. As the river valleys become deeper by erosion, springs break forth from the banks bounding the valleys, the waters being conveyed to the surface along the horizontal layer of porous gravel and sand. Such springs now exist in the deep valleys of the Red River of the North, and in the deep valley of the Sheyenne before it debouches upon the level plain of the bottom of Lake Agassiz above its own delta. Springs occur upon the level plain of the Red River valley, sometimes due to the hydrostatic pressure from the surface waters penetrating the ground upon higher land, which causes the soil water table to rise to the surface of the ground. A notable instance of this kind occurs along the front of the Sheyenne delta where crossed by the Fargo & Southwestern branch of the Northern Pacific railway at Woods station. Here a springy tract is caused by the waters which soak into the sandy soil of the Sheyenne delta and rise to the surface a few miles east upon the level plain which borders the delta.

Wells.—The conditions upon this area therefore render the problem of an adequate water supply from wells one of the greatest importance, since the sole dependence for the great majority of farm residents, as well as those living in towns, for a supply for all purposes, must be from this source, save only that which can be caught upon the roofs of buildings and stored in cisterns (an amount barely sufficient for strictly household purposes). The supply for drinking and culinary purposes for the cities of Fargo and Moorhead is derived from deep wells. Nature has, however, dealt bountifully in supplying water from wells. While nearly the entire water supply, as has been shown, must be derived from wells, over considerable areas flowing wells can be obtained from shallow depths, and upon the whole district an inexhaustible supply of fairly good water can be obtained with but little lift in pumping.

The wells of this region may be grouped into four classes: (a) Shallow surface or seepage wells; (b) deeper bored or tubular wells, in which the water rises due to pressure from a head; (c) artesian wells deriving their water supply from sand and gravel beds in the

drift, called Pleistocene artesian wells, and (d) artesian wells deriving their water supply from the Dakota sandstone.

There are comparatively few wells of the first class, and they are of little interest either from a geological or an economic standpoint. They are of interest as showing the height of the soil water table, and the fluctuations in its level during seasonal changes. The water in such wells is often strongly alkaline and unfit for any domestic use. The waters of the shallow wells, however, differ greatly in quality even in wells separated by very short distances and differing but little in depth. This circumstance shows the variability of structure and character of the deposits from the melting ice sheet which constitute the bottom of the ancient Lake Agassiz. Frequently dug wells furnish water which is of good quality from a digging having a gravelly bottom. When however the water is derived from a vein which contains a mixture of clay the water is very likely to be of a very strongly alkaline character and may contain other unpleasant or injurious impurities. The examination of waters from wells having clay bottoms indicates that the sediments deposited upon the bottom of glacial Lake Agassiz contained alkaline and other substances which render the water impure.

Two exceptions to the general conditions regarding surface wells are worthy of note. These are in the depth and character of the water of the wells on the sandy area of the Maple ridge, which traverses the course of the Maple river in Cass county, and in the wells on the Sheyenne delta plain in Richland, Cass and Ransom counties.

Upon these sandy tracts surface wells from twelve to twenty-six feet deep occur, furnishing inexhaustible supplies of water of very excellent quality. The water is usually contained in sand or fine gravel, and is commonly soft, and is perhaps the most nearly pure of any water in this portion of the state.

These conditions are explained by the sand deposits which act both as reservoirs and filters for the waters which fall upon the surface as rain and snow. The clay which underlies the beach sand serves as a dish to prevent the percolation of the water to lower depths, and the general surface is so free from any drainage slope that the water is held in the sand reservoir of the beach. Similarly on the delta plain clayey layers occur in the deposit sufficient to make the downward percolation of the waters slow. The sands both

Flowing Well and Tanks, Red River Valley.

Flowing Well, One-half Mile North of Mooreton, Richland County.

Flowing Well, Chaffee Farm, Casselton Quadrangle. Depth 431 feet; 1,000 barrels; Section 33 Township 138, Range 53.)

Flowing Well One-half Mile North of Woods, Cass County.

Digging Well—Driving Pipe.

Flowing Well. Just Struck, Trott Farm, Casselton Quadrangle. (Depth 418 feet, Flow at first, 4,000 bbls. per day. Section 10, Township 140, Range 53.)

of the beach and the delta were effectually washed by the waters of the lake during the time of their deposition, and thus were rinsed of the soluble salts such as impregnate the drift and lacustrine deposits generally.

Tubular Wells.—Tubular wells are common over nearly all parts of southeastern North Dakota, and furnish probably three-fourths of all the water used by the inhabitants for all purposes. By a tubular well is meant one made by boring with an auger, tubes thus made ranging in diameter from two to thirty inches. Frequently, however, a digging is made with a spade to a depth of twelve to thirty feet, and then an auger is used to penetrate deeper till the water bearing vein is reached.

Tubular wells range in depth from twenty to 200 feet, and the water often rises to within two to eight feet of the surface of the ground, and sometimes stands even with the surface. A generalized section of a boring for a tubular well would show black soil from two to eight feet from the surface, followed by stratified dark silt layers to a depth of thirty to seventy feet, and below boulder clay or till. The bottom of the drift is generally reached at depths not exceeding 200 feet from the surface, though the horizon between the drift and the shale cannot always be clearly distinguished owing to the similarity between the boulder clay and the shale-clay.

Sometimes the tubular wells derive their water supply from layers of sand in the lacustrine deposits, sometimes from gravel and sand at the horizon between the lacustrine silt and the till, sometimes in gravel and sand strata in the till, and again the vein may be struck at the bottom of the drift, while not infrequently the driller reports penetrating the "soapstone," the drillers' term for the Cretaceous shale-clay, before any water bearing vein of sufficient amount is struck.

From whatever horizon the water is derived, however, the same general conditions prevail determining the behavior of the water, viz., a compact and impermeable layer or bed of clay overlying the water bearing stratum, no sign of water appearing until the bottom of this clay is reached. The water rushes up the tube often with considerable force, and it is reported on good authority, in wells in which a digging had first been made and a hand auger used for the deeper boring, that it is sometimes with difficulty that the well digger is able to avoid being drowned before he could be lifted out of the

well. The supply of water is practically inexhaustible, it often being impossible to lower the water in the tube or digging to any appreciable extent even with the use of a wind mill or steam pump. Sometimes the water can be lowered appreciably by pumping, the water resuming its original height in the well within a short time after pumping ceases.

Pleistocene Artesian Wells.—It will be observed that the difference between the so-called "tubular" wells, in which the water rises nearly or quite to the surface of the ground, but does not actually flow, and an artesian well of the Pleistocene class, in which the water flows over the top of the tubing, is one of difference in the lifting pressure or head merely. Every gradation in head can be seen in the wells in this region, from those in which there is very little rising of the water in the tube but into which the water enters very readily, through the different heights to which the water is elevated in the tube to the flowing well in which there is a flow sustained by good pressure.

In the northern part of Cass county flowing wells are obtained at depths ranging from forty to 200 feet. There are also a few wells in the southwestern portion of Cass county in Davenport and Leonard townships, belonging to this class which range in depth from thirty to 175 feet. These wells do not flow with strong pressure, and the flow is subject to weakening. Such wells in some cases have ceased to flow entirely and have to be pumped. It is likely that in many cases the cessation has been due to faulty construction in the well tubing or to infiltration of sand, and not to any real loss of pressure due to the head.

A well in section 28, Davenport township, at a depth of eighty feet, yielded a strong flow of nearly 1,000 barrels when first drilled. Two wells in the northern part of the same section are respectively eighty-seven and 120 feet, both of these yielding only light flows. One of these, that at eighty feet, has ceased to flow and requires to be pumped. Another in the southeast corner of section 20 yields a small flow, and also one at 113 feet in section 34, a small stream. In section 11, Leonard township, a light flow was obtained from a depth of 101 feet, and in section 3 one at 175 feet, a quite vigorous flow was at first obtained, but soon became very light, furnishing an amount barely sufficient to supply the household and farm demands.

Flowing Well, Staples Farm, Casselton Quadrangle. (Depth 514 feet; Section 12, Township 140, Range 53.)

Same with Gauge Closed.

Lakes Formed from Staples' Well.

Tanks for Storing Water from Artesian Well of Light Flow. (Near Casselton, Dalrymple farm.)

Budke Well, Southwest of Wheatland. (Showing sand which has been thrown out of the well.)

Flowing Well, Thirty Feet Deep, Red River Valley.

These wells vary not only in the depth at which water is obtained, but also in the quality of water. In most cases the water is of fairly good quality for general purposes, and is not infrequently soft and suitable for laundry purposes. In none of these wells is there the characteristic saltiness which is uniformly present in the deeper artesian wells in which the supply is obtained from the Dakota sandstone. Shallow artesian wells also occur at a few places in Buffalo township, Cass county.

The Source of the Water.—The source of the water in these shallow flowing wells, like that of a great number of tubular wells in the district, is in beds of glacial gravel and sand. The great variation in the depth of these wells within short distances indicate that the veins which are the sources of the water are not only of different depths, but that these lie in comparatively narrow zones or belts, rather than in broad, widely extended sheets. A variation in depth between forty and 134 feet within a distance of less than two miles in the area of flowing wells in southeastern Cass county; three flowing wells having depths of 100, 125 and 145 feet, all within the area of one section in Spring Prairie township, Cass county, indicate distinct and separate reservoirs from which the water supply is derived in each case. Similar figures showing marked variation in the depths of the water veins in tubular wells where the water in each case rises within a few feet of the surface of the ground, but does not flow, are similarly explained. Four wells in section 34, Elmwood township, are respectively 90, 110, 117 and 201 feet in depth, and the water rises respectively to within four, nine, ten and sixteen feet of the top of the ground. Similar diversities in depth characterize the whole area.

It has frequently been observed that in the excavation or boring for a second well within a few rods or even a few feet from one which had furnished an abundance of water, but which had choked with sand or otherwise become disused, a thinner gravel or sand vein was encountered at about the same depth as the water bearing vein in the first well, but no water or but a scant supply was obtained. Sometimes no trace of such a vein as that which yielded the water in the first well was found in the second boring. It seems, therefore, that the gravel or sand veins are not continuous over large areas, and that they thin rapidly and cease altogether. It would seem, however, from the abundant supply of water and the strong

head in most of the tubular wells, and the Pleistocene artesian wells, that the veins extend for considerable distances along some line of direction.

The higher lands outside the limits of the Red River valley where frequent sandy and gravelly tracts occur, and where the surface drift is often loose and porous in texture, furnish a suitable gathering ground. Here the water falling as rain penetrates the porous soil and is conducted through the gravel beds to the lower levels. The preglacial valley in which Lake Agassiz existed formed a basin or trough in which the glacial materials were deposited from the ice sheet, and it is thus that porous tracts of gravel and sand may be so placed as to afford conduits or underground channels to convey the water which penetrated the grounds upon the higher lands outside the valley to the lower levels beneath the surface of the lake floor. The compact and impenetrable clay above and below the porous sandy or gravelly layers serves to effectually prevent the dispersion of the waters, and thus when a vertical boring from the level lake floor penetrates through the compact clay into the saturated sands and gravels the water in these layers immediately rises in response to the simple hydrostatic principle.

Some borings are recorded which penetrate to the bed rock, and no considerable amount of water was obtained. This is explained by the narrow areal extent of the water bearing layers, such borings having penetrated no veins of gravel or sand of such extent as to contain any large amount of water.

Wells of the Dakota Artesian Basin.—The western two-thirds of the Casselton quadrangle lies within the Dakota artesian basin. On this part of the quadrangle strong flows are obtained at depths ranging from 250 to more than 500 feet. The water is obtained in all cases from a fine-grained sand of loose texture. It is generally conceded that the formation from which the water is obtained is the Dakota formation.

The water in these wells is generally salt and not suitable for irrigation purposes, though it is not found to have any injurious effects upon animals that drink it, and it is quite agreeable to the taste after it has become habitual. The water is often not as hard as that obtained from the more shallow Pleistocene flowing wells, or the tubular wells.

The wells vary considerably in depth. This seems to be due to the occurrence of alternating layers of sandstone and shale, in some cases a sufficient flow being obtained in the first sand, and in other cases the second sand layer being penetrated, and not infrequently more than one water bearing vein is struck in the same boring.

In section 10, Walburg township, Cass county, two flowing wells about forty rods apart are respectively 265 and 440 feet in depth. Four miles north, in section 26, Gill township, water was obtained first at 362 feet, but insufficient in amount, and another flow in the same boring was struck at 405 feet.

In section 32, Amenia township, Cass county, two flowing wells one-fourth mile apart are respectively 350 and 450 feet deep. Five miles southeast, in section 21, Casselton township, two veins from which water flows over the surface of the ground were struck at 360 and 425 feet respectively. In the southeastern part of Walburg township, within a radius of one mile, occur five flowing wells at depths respectively of 240, 414, 430, 431 and 460 feet.

The granite bed rock has been struck in four places near the eastern edge of the Casselton quadrangle, at depths of 411, 460, 470, and 475 feet respectively, and very little water, or none at all, was obtained. The records of these borings so far as obtainable do not show the occurrence of the characteristic water bearing Dakota sandstone.

The pressure of the wells of the Dakota artesian class increases toward the west in this district. In the zone of the shallower wells of this class, those having depths ranging from 200 to 300 feet, the pressure is not great, and the water is generally not able to be conducted more than five or six feet above the surface of the ground. As the depth at which the water is obtained becomes greater toward the west, the pressure of the water becomes greater. In about the center of the Casselton quadrangle is a zone in which the calculated height to which the water might be carried, as determined from the well pressures, is 1,000 feet above sea level, or about fifteen to twenty feet above the surface of the ground. The 1,000-foot contour traverses nearly centrally the zone of wells of 300 to 400 feet in depth. Another contour line representing a height of 1,100 feet above sea level traverses nearly midway the zone of wells of 400 to 500 feet in depth, and lies about five to six miles west of and nearly parallel with the 1,000-foot contour. The height of the land

surface above sea level in this zone averages about 1,060 feet, giving a lift of the water above the surface of approximately fifty feet. From three to five miles west of this contour is another marking the 1,200-foot elevation above sea level, this contour traversing the territory which lies adjacent to the Red River valley, but beyond the area covered by the waters of Lake Agassiz. This contour in a general way runs parallel with the 1,100-foot and the 1,000-foot contours. The calculated height to which the well pressure would carry water in this region is from fifty to nearly 100 feet above the surface of the ground.

THE WATER SUPPLY OF THE TOWER QUADRANGLE.

By H. V. Hibbard.

Description of the Area.—The region included under the present discussion is approximately twenty-four miles wide and thirty-five miles long, its greater extent being from north to south. The northern boundary is about five miles north of and parallel with the Northern Pacific railway between Buffalo and Valley City. The western boundary runs through Valley City and follows nearly the course of the Sheyenne valley southward. The southern boundary runs east and west about one and one-half miles south of Fort Ransom.

A part of each of three counties make up the area of the Tower quadrangle. A portion of the northern part of Ransom county occupies the southern one-fourth of the quadrangle. The eastern third of the remainder is the southwest corner of Cass county. The southeast corner of Barnes county fills out the rest of the area.

The Water Resources.—As a fact of general interest under this subject it may be stated that since the annual rainfall is about twenty inches, and the rate of evaporation for the same time is about twenty-five inches, the only available supply of water, except that from artesian wells, is that which soaks into the earth and is retained in reservoirs of porous sand and gravel.

In considering the surface waters mention should be made of the streams both intermittent and constant, the lakes, undrained sloughs and ponds and springs.

Only one of the valleys or watercourses noted above bears a perennial stream, and that is the Sheyenne valley.

The Sheyenne river is a sluggish stream with many windings in the flood plain of its valley, about twenty feet wide, from a few inches to three or four feet deep, with steep mud banks, and flowing with a fall of one and one-third feet per mile. From Valley City south to Oakville it flows through a shale or gumbo region, having trees and shrubs only bordering its immediate banks. From Oakville to Fort Ransom and below the tree vegetation spreads farther out over the flats adjoining the river, and up the steep sides of the valley and penetrating the coulees but leaving off abruptly before reaching the prairie land beyond. During the rainy season this quiet river becomes quite a torrent sweeping across the intervening points between the bends but never reaching the second flats or cultivated bottoms above.

The Maple river is an intermittent stream. Its valley is dry throughout the greater part of the year except for sloughs and ponds of stagnant water which occur at intervals along its course.

Springs. — Springs occur along the valley of the Maple river and the Sheyenne and their tributary coulees. Usually the water from this source is usable, being free from alkaline and saline salts which contaminate the water from many shallow wells. Considering the living springs and those which may be uncovered by a little excavation this source of water supply is important, especially in the Sheyenne valley in the southwestern part of the quadrangle. A spring is merely a leak or emergence of the underground waters back to the surface. The general conditions necessary, therefore, for the development and maintenance of a spring are a sufficiently large gathering area, a subterranean reservoir consisting of a sufficiently porous and extensive stratum which outcrops in the surface or is connected with it by means of an impervious layer along which the water may flow.

The gathering area in this instance is the upland prairie bordering the Sheyenne or Maple rivers. The mixture of clay, sand, gravel and boulders, the so called drift, overlies the bed rock of shale of this region to a depth of about 100 feet. Throughout this drift, sand and gravel strata, and especially the terraced or shelf like deposits on the valley sides, occur. These then furnish ample store room for the collection of rainfall, and the impervious clay of the same drift or the shales beneath provide a floor for retaining the water and along

which they find their way to the outcrop on hill side or valley slope.

Sloughs and Ponds.—The landscape features which impress themselves upon the notice of the wayfaring man especially during the wet season are the ponds, sloughs and marshes. They are everywhere. Even in the immediate vicinity of the water courses they crowd up to the very banks. Here indeed one would expect the stream to turn aside or send a heading tributary back into and drain the ponds near by. But as before mentioned the valleys seem to be laid out without any reference whatever to the task of carrying away the surplus surface waters. As a matter of fact there are no modern or recently formed channels. The valleys and water-courses here formed were produced by the water flowing from a great sheet of melting ice which once overspread the entire prairie during the period in geological history known as the Ice Age.

As the dry season advances these surface waters rapidly waste away by evaporation. Only the deeper depressions retain a permanent supply; those whose depths reach below the permanent subterranean water level.

Subterranean Water. — The wells of this quadrangle, although varying greatly in depth, obtain their water supply from three different horizons corresponding to the rock structure underlying the region. The bed rock consists of shale or what is variously called "slate," "soapstone" or "hard pan." It is a clay formation, white or dark blue in color, and of fine texture and arranged in horizontal layers. Overlying this slate is a mantle or covering of what is called "drift," a mixture of clay, sand, gravel and large stones. The thickness of this mantle rock varies from a few inches to 150 feet. Over by far the greater part of the region the drift may average eighty feet in thickness. The greater number of wells reach water before penetrating this drift formation. The second water horizon lies in the shale or slate stone beneath the drift. The third horizon is that from which the artesian water is obtained and lies at a depth of from 400 to 600 feet.

In considering the wells of the first horizon, or those which do not penetrate the drift and enter the shale below, one finds great variation in the composition and arrangement of the components of the rock mantle passed through in order to reach water. Although this lack of definite order prevails a few general statements may be

made that hold good when a large number of well records are examined. As much as 75 per cent of the mantle rock of the eighty to 100 feet before noted is clay made up of the varieties yellow, blue and stony, but not generally hard or very tenaceous, there being a sufficiently large constituent of sand intermingled to make it light or easily worked. The remaining 25 per cent is made up of sand, quicksand and gravel. This is distributed through the clay in lenticular masses and layers varying from a few inches to several feet in thickness. This stratification of the lighter materials of the drift mantle though not generally horizontal in position are never pitched at very high angles. Where these layers of sand and gravel have considerable extent and thickness the more copious and better qualities of water are found. In general the following arrangement seems to be met with under average conditions: First ten to forty feet yellow stony clay with interspersed strata of sandy or gravelly composition, then blue clay also containing sand and gravel prevails until the bed rock or slate is reached. While this arrangement holds fairly good throughout the greater part of the quadrangle a few notable exceptions should be mentioned. These are the valleys and coulees of the Maple and Sheyenne rivers, the bluffs of the Sheyenne from Valley City to Oakville and the "Sand Prairie" region of Bear Creek and Oakville townships. In the Maple and its branches coarse sand and gravel with very little clay is found generally through the upper ten to thirty feet. Sand Prairie wells almost never penetrate clay but show stratified layers of coarse and fine sand. The water supply of the Sheyenne valley above noted belongs to the second water bearing or shale horizon, there being no mantle of drift material in that area. The quality of the water derived from this upper or drift horizon is variable, that from shallow wells, is frequently more or less alkaline, being obtained from surface wash or catchment basins of slight depth where alkaline salts have been lodged by upward seepage and subsequent evaporation of soil water. Water derived from the deeper wells in the blue clay, and especially those that reach the bottom of the drift near the underlying shale formation, are also liable to contamination from alkaline minerals. In general the best water especially for household use is that found at intermediate depths in the yellow clay or extensive sand and gravel layers. Regarding the distribution of the wells of the drift mantle over the eastern

three-fourths of the quadrangle a fairly constant relation holds between the depth of the wells and the topography.

Two ranges of townships, 55 and 56 west, those through which the Maple river flows, and the range adjoining on the west, may be considered as a zone of shallow wells. The average depth to an abundant water supply here lies between 30 to 60 feet. On the Alta ridge, range 57 west, the average depth of wells is about three times as great. A narrow strip along the eastern side, as far south as Eldred township, contains wells at considerable depths when compared with the Maple region immediately west. Continuing southward into Highland and Sheldon townships, good water but not an abundant supply for stock purposes, is found at slight depth of 20 to 40 feet. Another region of shallow wells, good and abundant water, is Sand Prairie in Bear Creek township. As before mentioned stratified sand and gravel constitute the structure to a depth of 40 to 60 feet. Being nearly surrounded by higher land, a large catchment area insures abundant supply, while the sand and gravel affords an extensive reservoir uncontaminated by any impurities. Not a few wells seven feet in depth supply good and abundant water.

In the clay region adjoining between Sand Prairie and Fort Ransom, water is reached with greater difficulty, and the supply and quality is somewhat uncertain.

From section 3, Oakville township, northward to Valley City in the vicinity of the Sheyenne, the quality of the water in general is distinctly and decidedly bad. Water here, either from shallow or deep wells, all in the shale rock, is charged more or less with salty and alkaline substances. For cattle and horses this water is available, but the human being not inured to such potions would best remain thirsty.

In the neighborhood of Valley City, northward four miles and eastward to the slope of Alta ridge, good water and an abundant supply is found from 25 to 50 feet in depth. The surface is a sandy loam underlaid by 25 feet of yellow clay, then follows blue clay with interbedded sand.

Regarding the water supply from what here has been called the second or shale horizon, little need be said. Usually water found under such conditions is scanty and not suitable for general use. It is surcharged with alkali and salt derived from the shale. A fair type of well in this horizon is one in Norman township, 138 N., R.

57 W., where the drill entered shale at a depth of 150 feet and the well was continued to a depth of 250 feet. Here a very slight amount of water was found and of bitter and alkaline taste.

Artesian Basin. — Throughout the eastern half of the quadrangle artesian water has been reached at a depth of from 400 to 600 feet. So far as present indications go it is safe to say that the artesian water yielding stratum lies at about the above depths under the entire area. Artesian wells are needed especially in the northern part of the quadrangle, and could doubtless be obtained if borings were made to the proper depth.

The quality of the artesian water so far obtained is fairly constant. The temperature is considerably higher than that of the shallow wells. It always contains the mineral compounds of salt, magnesia, alkalies, iron and sulphur, and these generally in sufficient quantity to impart a distinct taste to the water.

WELL RECORDS OF THE

(From the field notes of H. V.

Reference*	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 65	NW	19	136, 57	Preston	18	10
Page 64	NW	12	135, 57	Springer	33	16
Page 65		21	140, 58	Valley	30	10
Page 65	NE	16	140, 58	Valley	50	15
Page 65	SW	22	140, 58	Valley	23	18
Page 65		21	140, 58	Valley	45	25
Page 66	SW	21	140, 58	Valley	50	25
Page 66	SE	22	139, 58	No name	28	
Page 66	River bottom	34	139, 58	No name	40	
Page 66	S½ of SE	35	139, 58	No name	4	Flows
Page 66	E½ of NW	22	140, 58	Valley	14	10
Page 66	NW	18	138, 57	Norman	176	
Page 68	SE	30	138, 57	Norman	250	
Page 69	SE	10	139, 57	Cuba	107	
Page 70	E½	6	138, 57	Norman	50	
Page 70		18	138, 57	Norman	120	
Page 70	SW	28	139, 57	Cuba	90	
Page 71		14	138, 58	No name, near Daly		
Page 71	E½	4	136, 55	Liberty	27	18
Page 71	SE	4	136, 55	Liberty	470	Flows
Page 72	SW	34	139, 55	Hill	560	Flows
Page 73	SE	28	138, 55	Clinton	19	10
Page 74	SE	11	137, 56	Rariton	749	Flows
C62, 45	NE	24	137, 57	Thordenskjold	64	
C63	SE	24	137, 57	Thordenskjold	70	
C65, 45	E½	25	137, 57	Thordenskjold	57	
C66	SW	30	137, 56	Rariton	72	
C68	NE	30	137, 56	Rariton	68	
C70	SE	31	137, 57	Thordenskjold	87	
C71	SW	26	137, 57	Thordenskjold	85	40
C69	SE	33	138, 55	Clinton	31	10
D 4, 51	SW	26	138, 56	Binghampton	15	5
	NW	26	138, 56	Binghampton	15	6
	E½	22	138, 56	Binghampton	22	
	SE	14	138, 56	Binghampton	23	7
	NE	14	138, 56	Binghampton	42	
					44	
	SE	2	138, 56	Binghampton	19	
		4	138, 56	Binghampton	33	15
D18, 53	NE	8	138, 56	Binghampton	30	17
D83	NW	17	138, 55	Clinton	33	
D86	SW	5	139, 55	Clinton	50	

* References are to pages and paragraphs in Field Note Books.

TOWER QUADRANGLE

Hibbard and Daniel E. Willard.)

Yield	Character of Rock	Character of Water	Remarks
Plenty	2 soil; 16 gravelly sandy clay.	Good	This is 30 ft. above river surface.
Plenty	Soil 3.9 ft. yellow clay; 21 ft. blue (shale) clay	Good	12 to 15 ft. above river level.
Plenty	6 ft. soil; gravel 24 ft	Good	
Plenty	All clay; brown gumbo	Bitter alkali, bad	In North Valley City.
Plenty	Blue clay (sticky)	Good	15 or 20 ft. above river level.
Plenty	"Black soil" clay 20 ft.; 10 ft. gravel; 5 ft. blue clay.	Good	On terrace 6 blocks NW. "Kindred Shale" at 45 ft. in Valley City.
Plenty	All gravel	Good	In Valley City gravel terrace.
...	Soil 6 ft; 22 gravel	Good	60 rods from river.
Plenty	All gumbo	Alkali	Down on river bottom.
Abundant	Gravel bank, shale at bottom	Good	A good spring.
Plenty	Sandy loam	Good	Valley City near R. R. bridge, first terrace 15 ft. above river level.
Slight	30 ft. yellow clay till; 115 blue clay; 15 ft. sand; 3 ft. hard pan; 10 blue clay; 2 hard pan; 1 ft. gravel and slate	Good	I think drift was passed at about 80 ft. here.
None	Yellow clay 12 ft.; blue clay 138; "soapstone" at 150 ft.	...	This shows drift 150 ft. here.
...	No shale or soapstone; blue clay in bottom	...	Drift mantle here over 107 ft.
Plenty	2 ft. soil; 16 ft. yellow clay; 32 stony blue clay	Good	A well ½ mile E. of this is 90; no shale; all drift.
...	120 clay, drift, just into shale	...	Penetrated drift to shale.
...	90 ft. drift to shale	Good	Drift here 90 ft.
...	...	...	Good springs in this section.
Plenty	Soil 8 ft.; clayey sand 8 ft.; gravel 2 ft.; 9 ft. blue clay	Good	At Enderlin in Maple valley an alluvial deposit to shale.
Large	Rock record no good	...	A good flow at 225 ft.
1.410 bbls. per day	Stony clay to 220 ft.(?) then shale to bottom	Soft saline, good.	Strong flow brings up fragments of shale. Mr. Card's well.
Plenty	Loam 2 ft.; 17 ft. sand and gravel	Good	On "first" terrace in Coulee of Maple river ∴ gravel train.
Big	"First 100 ft. difficult drilling on account of stone; ∴ drift. Mr. P. Little, Prop.	Good	Meagre record; nobody knew.
Scant			
...	Gravel at bottom		
Plenty	Sand at bottom		
Scant	Gravel at bottom	...	Bored; 28 inch hole.
Scant	Gravel and quick-sand at bottom.	...	Bored.
Plenty	Gravel and sand; soapstone at 150	...	Bored; 32 inch.
...	...	...	Bored.
Plenty	Sand and gravel.		
...			
...			
...	Blue clay; quicksand	Good	
...			
...			
Plenty			
Plenty	Blue clay gravel bottom		
Plenty	Glravel bottom		
Plenty	Blue clay and gravel		
Plenty	Gravel and sand at bottom	Good	
Plenty			

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
D92	NE	30	139, 55	Hill	20	
	SE	19	139, 55	Hill	40	
	SE	20	139, 55	Hill	51	35
	SE	18		Hill	45	
E1, 68	NW	31	140, 54	Buffalo	28	
E2	SE	1	139, 55	Hill	60 to 225	
E9, 70	SW	4	139, 55	Hill	48	25
			139, 55	Hill	60	20
E15, 71	N½	35	140, 56	Oriska	22	
	NW	34	140, 56	Oriska	26	3
	SW	30	140, 56	Oriska	20	6
			140, 56	Oriska	46	
E17, 72	SE	25	140, 57	Alta	25	
		35	140, 57	Alta	92	70
		34	140, 57	Alta	42	
E24, 73		32	140, 57	Alta	125	10
73		31	Lanona	Alta	10	5
E27, 74		6	139, 57	Cuba	36	
E30, 74			139, 57	Cuba	40	3
E31	SE	6	139, 57	Cuba	35	
E33	NW	8	139, 57	Cuba	90	
E34	NW	9	139, 57	Cuba	120	60
E38	NE	2	139, 57	Cuba	100	16
E49, 79	SW	20	139, 57	Cuba	270	
	NW	20	139, 57	Cuba	80	
Page 74		31	137, 55	Pontiac	50	25
Page 88	SE	31	137, 57	Thordenskjold	96	70
Page 25, B. 23	SW	28	137, 54	Highland	42	25
Page 26, B. 25	SW	32	137, 54	Highland	32	20
Page 26, B. 26	SE	14	137, 55	Pontiac	48	25
Page 27		18	136, 55	Liberty	80	
Page 30	SE	34	136, 55	Liberty	36	25
Page 30	NE	26	136, 56	Moore	50	30
Page 31, B. 40	NW	11	135, 57	Spring	28	
Page 34		10	135, 57	Spring	40	30
Page 34	NW	17	135, 55	Casey	50	30
Page 34	SE	8	136, 55	Liberty	50	40
Page 85, B. 44	NW	18	136, 55	Liberty	80	50
Page 36, B. 47	NW	1	135, 56	Fuller	35	15
Page 37	SW	1	135, 56	Fuller	36	30
Page 38, B. 50	NW	3	135, 57	Springer	66	40
Page 39	NE	7	135, 57	Springer	70	
Page 39	NE	7	135, 57	Springer	35	
Page 40, B. 52	SW	24	135, 58	Ft. Ransom	224	30
Page 40, B. 53	NW	23	135, 58	Ft. Ransom	60	40
Page 40	NE	16	135, 58	Ft. Ransom	20	14

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty	...	...	Dug.
Plenty	Blue clay.		
Plenty	Gravel at bottom.		
Plenty	Gravel and quicksand.		
...	...	Alkali	Wells drilled here 150 ft.; water bad; alkali.
Scant	Blue clay	Hard	
Plenty	...	Poor.	
...	Quicksand at bottom	Good.	
...	Gravel at bottom	...	Dug.
Plenty.			
Plenty	Gravel	Good.	
...	...	Good.	
Scant.			
...	...	Good; hard.	
Plenty	...	Poor.	
Plenty	...	Good.	
Plenty	Sand.		
Plenty	...	Good.	
...	Gravel.		
Plenty	Dug 75; clay	Alkali	3 ft. diameter.
Scant.			
Plenty	Gravel, 20 ft.; blue clay, 5; quicksand, 25	Good	In side of Maple coulee.
			Summary of wells NE. Valley City on tower sheet: 25 to 50 ft. deep; blue clay at 25 ft.; water abundant, good; yellow clay 25 ft.
Plenty	Sandy soil, 3 ft.; yellow clay, 10 ft.; blue clay, 80; gravel, 3 ft	Good	Strong ground, morainic in vicinity.
Plenty	Clay (yellow), 20 ft., blue clay, 20 ft.; gravel, 2 ft.	Good	In Maple coulee.
Plenty	Sandy loam, 8 ft.; sand, 4; gravel, 4; blue clay, 14 ft.; coarse cobble, 2 ft.; clay with coal masses scattered thru it: this is carbonized wood of drift origin	Good	In bottom of Maple coulee
Plenty	47 ft. clay till; 1 ft. shale	Good.	
...	Shale at bottom	...	Drift 80 ft. thick.
Plenty	Clay, 30 ft., blue clay, 3 ft.; quicksand, 3 ft.	Good.	
Scanty	No clear record.		
...	Clay (yellow, stony), 12; blue clay, 12; gravel, 4		
Plenty	Soil, 4; clay, 8; clay and sand, 28	Good.	
Plenty	40 ft. clay drift; 10 ft. coarse sand	Good	Well bored at Buttzville.
Plenty	48 ft. clay drift; 2 ft. gravel.	Good.	
Plenty	60 ft. till.; 5 ft. gravel; 15 ft. hard blue clay, shale perhaps	Good.	
Plenty	Soil, 2 ft.; yellow clay, 24; sandy blue clay, 8 feet; coarse gravel, 1 ft.	Good.	
Plenty	Soil, 3 ft.; sandy red clay, 6 ft.; blue clay, 25 ft.; 2 ft. gravel	Good.	
Scanty	Soil, 2 ft.; hard pan clay, 64 ft	Good.	
...	70 ft. stony clay drift	...	No water.
...	35 ft. coarse gravel	...	In coulee bottom.
Scanty	2 soil, 50 ft. stony clay, 172 blue clay not stony	Good	Indicates drift 50 or 60 ft.
Plenty	Soil 3 ft., 7 ft. yellow clay, blue clay 30	Good.	
Plenty	All sand	Good	On moraine.

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 41, B. 57	NE	8	135, 58	Ft. Ransom	15	....
Page 41, B. 58	SW	9	135, 58	Ft. Ransom	20	....
Page 43, B. 59	NE	32	135, 58	Ft. Ransom	14	....
A52	NW	8	140, 55	Tower	70	50
B32	SE	32	137, 54	Highland	515	Flows
B32	NW	19	139, 54	Howes	85	....
A29	SW	4	140, 56	Oriska	37	....
A38	NW	8	138, 55	Clinton	40	20
A64	NW	29	141, 54	Ayr	28	18
A66	E½	34	141, 54	Ayr	117	95
A1	NW	18	140, 55	Tower	32	10
A13	....	11	140, 55	Tower	30	Flows
A14	SE	15	140, 55	Tower	48	Flows
A16	SE	13	140, 55	Tower	606	Flows
	SE	4	137, 54	Highland	500	Flows
B18	E½	8	137, 54	Highland	30	20
Page 49	SE	12	135, 58	Ft. Ransom	44	25
Page 49	SW	2	135, 55	Ft. Ransom	156	....
Page 49	NW	2	135, 55	Ft. Ransom	170	....
Page 49	NW	5	135, 57	Springer	96	80
Page 58	....	7	135, 57	Springer	100	....
Page 58	....	8	135, 57	Springer	100	....
Page 58	....	5	135, 57	Springer	....	....
Page 58	SW	28	136, 57	Preston	175	....
Page 59	....	8	136. 57	Preston	180	....
Page 59	NW	18	136, 57	Preston	14	8
Page 60	SE	2	135, 58	Ft. Ransom	56	40
Page 60	NW	2	135, 58	Ft. Ransom	105	....
Page 60	NW	25	136, 58	Bear Creek	10	6
Page 60	NW	13	136, 58	Bear Creek	41	25
Page 60	NE	14	136, 58	Bear Creek	40	20
Page 61	NE	14	136, 58	Bear Creek	25	16
Page 61	....	26	137, 58	Oakville	50	30
Page 62	NW	3	136, 58	Bear Creek	34	24
Page 62	SE	1	135, 58	Ft. Ransom	30	20
Page 55	SE	12	135, 58	Ft. Ransom	22	....
Page 55	NE	12	135, 58	Ft. Ransom	70	23
Page 56	NE	12	135, 58	Ft. Ransom	40	16
Page 57	NW	18	135, 57	Springer	22	10
Page 2, A3	NE	6	139, 54	Howes	200	....
Page 3, A8	NW	5	138, 54	Eldred	70	30
Page 3	SE	4	138, 54	Eldred	....	Flows

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty	Clay and sand mixed	Soft, good.	
Plenty	All hard clay	Good	
Plenty	Sand and gravel; blue clay at bottom	Good.	
Plenty	Clay 68 ft.; quicksand 2 ft.	Slightly alkaline; good	Dug 45 ft; drilled 25 ft.
...	No record	Alkaline; salty.	
Abundant	Till., 65 ft.; sand, 10 ft.	Good.	
Light	Sandy clay	Good.	
Plenty	Clay, 30 ft.; sand, 10 ft.	Good	Land gently rolling.
Plenty	Clay, drift	Slightly alkaline.	
Plenty	Yellow clay, 25 ft.; blue clay, 25 ft.; blue clay and sand, 67 ft.	Good	Wells within two miles, 40 ft. deep, give abundant and good water.
Abundant	Clay, 22 ft.; blue clay, 10 ft.	Alkaline.	
...	Drift.	Good.	
Abundant	In bottom of Maple coulee	Good	A two-inch stream rises 10 ft. above ground.
Abundant	150 ft. clay; 10 ft. hard pan; 446 ft. black clay	Good	Character of rock, record not reliable. Senator Talcott's well.
---	No record	Alkaline; bitter.	Boyle well.
Plenty	In drift	Good.	
Plenty	Yellow clay, 15 ft.; 29 ft. blue slate	Salty	Usable.
---	40 ft. clay and stony gravei; 116 ft. shale		
---	45 ft. yellow clay; 130 ft shale.		
Slight	20 ft., gravelly clay; 12 ft., sand; 12 ft. sandy clay; 46 ft. slate; 6 ft. sand	Bad; alkaline	Not usable.
---	...	...	This well passes into shale. At what point eould not learn.
---	...	...	Same as above.
---	...	...	This section house abandoned; no good water.
Plenty	Clay; no shale(?)	Good	Bored 2-inch hole.
For house	Clay, 110 ft; 80 ft. red clay and gravel	Good.	
Plenty	Clay, 12 ft.; coarse gravel, 2 ft.	...	Good springs in valley here. Sheyenne river.
Plenty	Drift, 56 ft.	Good	Shale at bottom.
...	Clay (stony), 100 ft.	...	Shale said to be within 100 ft. Improbable.
Plenty	All gravel	Good	On Sand Prairie.
Plenty	1 ft. soil; 5 ft. clay; 35 ft. sand	Good	On Sand Prairie.
Plenty	All clay	Good	Heavy soil, gently rolling land.
Plenty	Clay	Good	Heavy clayey soil; gently rolling.
Plenty	Clay	Good	45 ft. seems to be shale.
Plenty	Soil 2 ft.; sand and gravel.	Good	Sand Prairie; very level.
Not abundant	All clay (till)	Good	Gently rolling; overwash plain is indicated by sandy surface of topography.
Plenty	2 ft. soil, clay; 10 ft. yellow clay; 10 ft. blue clay.	Hard; good.	In valley of Sheyenne, second terrace.
Plenty	Clay soil, 1 ft.; soft stony clay (till), 18 ft.; blue clay, hard, not stony (shale), 51 ft	Good	On side of coulee, 60 ft. above river bed.
Plenty	20 ft. glacial drift; 20 ft. blue shale	Soft; good.	In mouth of coulee, 60 ft. above river bed.
Plenty	In sandy, black alluvium; no shale	Good	12 ft. above river surface.
...	Probably drift		
...	...	Alkaline.	

* 125 barrels.

WELL RECORDS OF T

Reference	Quarter	Sec.	Twp & Range	Township	Depth	Heigh Wat
Page 3	SE	9	138,54	Eldred	565	....
	SE	18	138,54	Eldred	115	
Page 4, A15	NE	8	137,54	Highland	513	Fl
Page 4	W½	8	137,54	Highland	32	....
Page 4	SW	6	137,54	Near Enderlin	40	....
Page 6, A31	NW	24	136,55	Liberty	27	....
Page 6	NW	18	136,54	Sheldon	23	....
Page 8, A51		....	135,58	Ft. Ransom	35	....
Page 9, A56	NE	5	135,57	Springer	90	....
A61	SE	34	136,57	Preston	70	....
A62	NE	2	136,57	Preston	53	....
Page 10, A63	NW	2	136,57	Preston	53	
Page 10	NW	6	135,56	Fuller	32	....
Page 10, A65	SE	30	136,56	Moore	40	....
Page 10, A66	SE	6	135,56	Fuller	70	....
Page 10, A67	NW	8	135,56	Fuller	46	
		17	135,56	Fuller	....	....
Page 11, A69	SW	8	135,56	Fuller	68	
	NE	8	135,56	Fuller	40	....
Page 13, A74	NW	9	135,56	Fuller	60	
Page 13, A79	SE	33	136,56	Moore	58	....
Page 13, A81	NE	15	136,56	Moore	142	....
Page 14, A82	NW	34	136,56	Moore	40	....
Page 14, A83	SE	28	136,56	Moore	66	....
Page 43, B61		34	136,58	Bear Creek	34	
Page 44	SE	26	136,58	Bear Creek	12	
Page 44	SE	22	136,58	Bear Creek	6	
Page 44	NE	26	136,58	Bear Creek	68	
Page 44	SE	23	136,58	Bear Creek	10	
Page 44	SW	22	136,58	Bear Creek	50	....
Page 46	W½ of SW	13	136,58	Bear Creek	25	....
Page 46	NW	10	136,58	Bear Creek	28	....
Page 47	SE	15	136,58	Bear Creek	28	....
Page 48	SW	11	135,58	Ft. Ransom	....	Fl
Page 48	SW	12	135,58	Ft. Ransom	38	....
Page 48	NW	12	135,58	Ft. Ransom	71	
Page 49	SE	12	135,58	Ft. Ransom	44	....
Page 49	SW	2	135,58	Ft. Ransom	156	....
Page 49	NW	2	135,58	Ft. Ransom	170	....
Page 49	NW	5	135,57	Springer	96	....
Page 50	Center of	12	135,58	Ft. Ransom	42	....
Page 50	NW	1	135,58	Ft. Ransom	42	
Page 52	SE	28	136,58	Bear Creek	50	....
Page 53	NE	30	138,58	Bear Creek	4	
Page 53	SW	18	135,57	Springer	....	Fl
Page 53	SE	4	136,58	Bear Creek	30	
Page 53	NE	3	136,58	Bear Creek	39	
Page 54	NE	34	137,58	Oakville	32	
Page 54	SE	29	137,58	Oakville	20	

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
900 barrels.			
Fair	...	Alkaline.	
...	...	Salty.	
Good.			
...	20 ft. clay		
...	Clay, 25 ft.; quicksand, 2 ft.		
...	All sand		
Good	All drift	Good.	
Scant	...	...	Several wells similar in character; scant supply of water.
Scant	Drift.		
Plenty	Drift; gravel at bottom	...	Coal vein 1 ft. thick.
...	Drift: quicksand.		
Plenty	...	Alkaline.	
Plenty.			
Plenty	Drift.		
Spring.			
...	Gravel	Good.	
...	Gravel bottom.		
Plenty	60 ft. clay	...	Hardpan at 100 ft.
Plenty	Clay and blue clay.		
Plenty	Gravel and blue clay	...	Dug.
Plenty	Gravel, 4 ft.; 30 ft. blue clay	Alkaline; poor quality	Dug well.
Plenty	All quicksand	Good	Old flood plain of Sheyenne river.
Plenty	In clay	Good	Sand Prairie.
Plenty	Blue clay	Alkaline; salt.	
Plenty	Clay	Good.	
None	Blue clay.		
Plenty	All fine sand	Good.	
Plenty	Soil, 2 ft., sandy; sand, 24 ft	Good	Level; Sand Prairie.
Plenty	26 ft. clay; 2 ft. sand	Good	Gently rolling; edge of Sand Prairie.
Plenty	...	Good	Perennial spring.
Plenty	Sand, clay, gravel	Good	In alluvium of Sheyenne valley.
Plenty	4 ft. loam soil; 25 ft. gravelly clay; 1 ft. hardpan; 41 ft. shale	Bad; alkaline	On Sheyenne valley bottom.
...	15 ft. yellow clay; 17 ft. blue shale	Alkaline; salty.	
None	40 ft. clay and gravel; 116 ft. slate-shale	...	No water; so-called dry well.
...	45 ft. yellow clay and gravel; 125 ft. slate-shale		
...	20 ft. gravelly clay; 12 ft. sand; 12 ft. sandy clay; 46 ft. slate rock (shale); 6 ft. sand	Poor quality	Not usable.
...	20 ft. sandy clay; 22 ft. black clay; 1 ft. gravel	Very poor	Water unfit for any use.
Plenty	40 ft. clay (till); 2 ft. sand	Good	At foot of hill in valley. In till from hillside wash.
Abundant	50 ft. till	Good	On moraine 1½ mile east of Sand Prairie.
Plenty	All in gravel	Good; hard	Level; Sand Prairie. Surface very stony.
Plenty	...	Good	A fine spring; water charged with iron.
...	1 ft. sandy soil; 29 ft. fine sand	Good	Level; Sand Prairie; dug well.
Plenty	1 ft. soil, sandy; 38 ft. sand and gravel	Good	Level topography; Sand Prairie.
Plenty	1 ft. sandy soil; 1 ft. gravel; 30 ft. sand and gravel	Good.	
Plenty	All in sand and gravel	Good	At Soenby; several wells near, all in coarse sand and gravel 10 to 20 ft.; overwash plain.

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 54	NW	34	137, 58	Oakville	20	7
Page 54	SE	28	137, 58	Oakville	50	....
A89, page 14	SW	33	136, 56	Moore	72	
A91, page 14	SW	....	136, 55	Liberty	50	25
A93, page 14	NW	30	136, 55	Liberty	60	....
A95, page 15	SE	12	136, 56	Moore	50	....
A97, page 15	SE	20	136, 55	Liberty	80	20
A99, page 15	NE	32	135, 55	Casey	42	....
B2, page 16	....	....	136, 54	Sheldon	17	....
B3, page 16	....	....	136, 54	Sheldon	18	....
B5, page 16	....	....	136, 54	Sheldon	30	4
B13, page 17	SE	2	136, 54	Sheldon	30	4
B15, page 18	NW	12	135, 55	Casey	28	4
B23, page 19	NW	4	136, 55	Liberty	65	....
B24, page 19	Center	4	136, 55	Liberty	54	....
B26, page 20	NE	7	136, 55	Liberty	12	....
B28, page 21	NE	12	136, 55	Moore	46	....
B31, page 22	NW	10	136, 56	Moore	40	....
B32, page 22	SW	13	136, 56	Moore	40	....
B34, page 23	NW	9	136, 56	Moore	60	30
B39, page 24	Center	6	136, 56	Moore	45	27
B40	SE	1	136, 57	Preston	30	15
B58, page 27	NE	20	136, 56	Moore	75	....
B59, page 27	SW	16	136, 56	Moore	50	....
B66	SW	22	136, 56	Moore	70	18
B67, page 29	NE	26	136, 56	Moore	76	....
B68	NW	25	136, 56	Moore	32	2
B85, page 33	SE	20	136, 55	Liberty	65	
B91	SE	8	136, 55	Liberty	56	2
B93, page 34	SE	28	137, 55	Pontiac	41	....
B94	NE	28	137, 55	Pontiac	52	....
B95	NW	26	137, 55	Pontiac	80	....
B99, page 35	SW	32	137, 55	Pontiac	45	8
C6, page 35	NW	24	137, 55	Pontiac	90	....
C7	SE	14	137, 55	Raritan	38	20
	Lucca City	....	......	....	*20 to 26	....
			137, 56	Raritan	20 to 50	....
C43, page 41	....	....	137, 57	Thordenskjold	125	....
E73, page 84	NW	11	138, 57	Norman	7	....
E97, page 87	SE	35	139, 56	Springvale	35	

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty	All coarse gravel and sand	Good	Near Soe nby; overwas plain.
Plenty	Soil, 2 ft.; clay and boulders, 30 ft.; coarse sand, 15 ft....................	Good	
Plenty	Gravel bottom.		
Plenty	....	Hard.	
Plenty	....	Good.	
Plenty	Quicksand and gravel at bottom.		
Plenty.			
Plenty	Clay to sand at bottom	Good.	
Plenty.			
....	Much quicksand; sandy clay......................	Good.	
Plenty	Gravel at bottom.		
Scant.	Blue clay, sand and gravel		
Plenty	Brown clay		
Plenty			
Plenty	Sand and gravel...........	....	In coulee.
Plenty	Gravel at bottom.		
....	Gravel and blue clay.		
Scant............	Hard blue clay at bottom.		
Plenty.			
Plenty.	Sand and gravel at bottom		
....	15 ft. yellow clay; 15 ft. blue clay.		
Scant............	Blue clay and quicksand.		
Scant............	....	....	Hard to get water.
....	Gravel at bottom.		
....	Hard, blue clay............	....	Very difficult to get water.
Plenty.			
Scant.			
Plenty	....	....	Dug 25 ft.; drilled 16 ft.
Not abundant	Quicksand and gravel	Good	In Maple valley.
....	Blue clay at bottom.		
Plenty	Sand and gravel,..........	....	Dug.
Plenty	Clay and sand.		
Plenty	Clay and sand.		
Plenty	Gravel vein supplies water		
Plenty	Quicksand and gravel veins	Good.	
Plenty	....	....	Bored 2-inch hole.
Plenty	....	Alkaline.	

THE WATER SUPPLY OF THE ECKELSON QUADRANGLE.

By William H. Westergaard.

The Eckelson quadrangle includes the region lying between 98 degrees and 98 degrees 30 minutes west longitude and 47 degrees and 47 degrees 30 minutes north latitude. Its length is approximately thirty-four and one-half miles in the north and south direction, and its width twenty-four miles from east to west. Its northern boundary is approximately one and one-half miles north of the northern boundary of the tier of townships numbered 140, or about five miles north of the main line of the Northern Pacific railroad. The eastern boundary passes directly through Valley City, includes portions of the Sheyenne valley and passes Kathryn and Fort Ransom about three miles to the west. The southern boundary lies nine miles south of the Barnes and Ransom county lines, which is approximately nine and one-half miles south of LaMoure, and two and one-half miles south of Dickey. The western boundary crosses the main line of the Northern Pacific railroad one-half mile west of Spiritwood, and passes Dickey one and one-half miles to the west.

The area included in the Eckelson quadrangle comprises portions of four counties, viz., Barnes, Stutsman, LaMoure and Ransom. The southwestern portion of Barnes county constitutes at least two-thirds of the northwestern portion of the quadrangle. Stutsman county is represented by a strip twenty-four miles long and three miles wide along its eastern border, LaMoure county by a portion from its northeastern corner twenty-two and one-half miles long and nine miles wide, and Ransom county by a small strip from its northern and western corner nine miles long and one and one-half miles wide.

Water Resources.—The available water supply of any region may be classed as surface water supply and subterranean water supply. Under the head of surface water supply we may consider streams, lakes, sloughs, ponds and springs. Under the head of

subterranean water supply we may consider the water which is obtainable in wells by digging, boring or drilling.

Subterranean Water.—In general the wells of the Eckelson quadrangle obtain their water supply from three different horizons or water levels. With regard to these horizons we may group the wells into three quite distinct classes. The first consists of the wells in which a water supply is obtained without penetrating the bed rock or shale. These are the shallow wells dug in the drift material over or above the shale. The second class consists of those wells which penetrate the bed rock or shale. These are the deeper wells, which are usually bored to some water vein of sandy material in the shale. The third class consists of those wells known as artesian wells in which water is found under shale. These wells are drilled through the shale formations to a water bearing "sand rock" or sand stone.

Wells Which Do Not Penetrate the Shale.—The chief source of a permanent water supply aside from the deep tubular and artesian wells consists of wells dug to water which soaks through the surface material to reservoirs of porous substances like sand or gravel. These are the ordinary dug wells which penetrate the drift to depths varying from ten to 125 feet, the average depth being from twenty to forty feet.

The material in which these wells are dug consists of the "mantle" or top layer of material called "drift" which covers the bed rock or shale of this area to depths of from ten to 125 feet. This "drift" is a heterogeneous mixture consisting of what is commonly called clay mixed with sand, gravel, and bowlders. The sand and gravel may be quite evenly or uniformly mixed with the clay or it may be found in layers or veins varying from a few inches to several feet in thickness. It may even be found in pockets and often in streaks running through the clay. Usually the sand and gravel layers show a stratification of the finer material, the stratification tending to be horizontal though not necessarily so. These variations are due to the morainic origin of this drift material, it having been brought and left by the glaciers at the time known as the "Ice Age."

In spite of the fact that these wells show such a wide variation in depth, material passed through, and in the supply and value of the

water obtained, a few general statements may be made. Clay constitutes at least three-fourths and perhaps four-fifths of the material. Wells dug where the surface features are markedly morainic are usually dug through more gravel and sand near the surface. The clay is also more stony, *i. e.*, more mixed with sand, gravel and bowlders, and in general the chances are better for striking some water reservoir at a shallow depth. Wells dug in river benches are usually dug almost entirely in gravel and sand. The average well on the Eckelson quadrangle is dug from ten to forty feet in a whitish-yellow oxidized clay in which are interspersed a number of layers of sand and gravel commonly called water-veins. Beneath the yellow clay is found a harder, dark colored unoxidized clay called blue clay in which are also found a number of gravel and sand reservoirs called "water veins." This blue clay, sometimes very much mixed with sand and gravel, constitutes the material lying between the yellow clay and the "bed rock" or shale. From a study of numerous well records it would seem as though the sand and gravel water-veins were more numerous in the yellow clay than in the blue clay. Usually a water bearing stratum is struck between yellow and blue clay, the blue clay forming a harder and more impervious layer than the yellow. If a good supply of water is not secured after penetrating the yellow clay a better supply can usually be obtained by going deeper into the blue clay. The water-vein in this case is usually quicksand, though it may be sand or gravel. A stratum of quicksand usually has a hard layer over it called "hard pan," consisting of a mixture of clay, sand and course gravel. The water often rises with considerable force when this "hard pan" layer is pierced, especially where the water bearing stratum is of considerable extent and thickness.

The best kind of a well for general purposes is one dug in yellow clay to a water-vein of sand or gravel. The water in this kind of a well is seldom under very high pressure, and does not rise to any considerable extent above the water-vein. Under these conditions no large quantity of water will be allowed to stand in the well and become contaminated or dissolve large quantities of the soluble salts from the material constituting the wall of the well. Water in very deep wells is usually bad, because a water-vein under high pressure is struck, and a large amount of water is allowed to stand

in the wells and dissolve the alkalies and other soluble salts constituting such a large amount of the soluble material of the clay walls.

In the southwestern part of the Eckelson quadrangle is a region called "Sand Prairie" which constitutes the greater part of Bear Creek, southern Oakville, and northwestern Litchville townships, extending from there into the Tower sheet on the east. This region is very level land, and appears to have been a lake bed in glacial time. The wells here are very shallow, being dug in stratified sand to a depth of from seven to twenty feet. The water is very good, but very slightly hard. The average depth of the sand is probably about thirty or forty feet.

A small, sluggish intermittent stream called Bear creek winds its way from the Sand Prairie region southward to the James river. Good water in sufficient quantity is very hard to obtain in the region immediately west of Bear creek in eastern Litchville and southwestern Bear Creek townships. The reason for this scanty water supply is that the shale is found a few feet beneath the surface, and in this shale very few water bearing strata are found, and where found, usually yield water unsuited to general uses.

In the vicinity of the city of Litchville, in southwestern Lincoln and northwestern Prairie townships, good water is hard to obtain. Wells are frequently dug to depths of sixty to 125 feet, but the supply of water is scanty and usually of poor quality, being very hard and alkaline. No strong water bearing stratum is ordinarily found here in penetrating the drift to the shale or "slatestone" bed rock.

In the region near to the James valley on either side, in Roscoe, southern Saratoga and southwestern Sheridan townships, good water of sufficient quantity is usually obtained by digging the well in some coulee or ravine having drainage into the James river. Usually a stratum of gravel or sand may be struck at quite shallow depths near the bottom of these coulees or "water-ways." In the higher land many wells have been dug to shale, but quite often very little water and of an inferior quality is obtained.

The conditions immediately west of the Sheyenne valley are somewhat similar to those adjoining the James valley. Water is hard to obtain on the high areas. Shale is struck before any water bearing stratum of much consequence is reached.

Another region where good water is obtained with difficulty is found in the eastern portion of township 40, range 61, in the vicinity of Eckelson, and west of Eckelson lake. A plentiful supply of water can usually be obtained in deep wells, but it is usually very hard and alkaline.

In southern Prairie and southwestern Litchville there are considerable areas where water is obtained almost invariably in sufficient quantity in quicksand. Throughout the quadrangle there are numerous other localities of similar extent where water is obtained in quicksand, southern Spring Creek and northern Scandia being examples.

The region immediately surounding Sanborn, in central Potter and Marion, in northern Sheridan towships, are examples of localities where good water is ordinarily obtained at depths of thirty to thirty-five feet.

In the markedly morainic regions the wells vary most widely in character, but here wells of good water in abundant supply are nearly always obtainable if good judgment is exercised in selecting a locality.

There are a few wells in this quadrangle, usually bored wells, which have been sunk deep enough to penetrate the shale. In some of these strong water bearing strata have been struck, but usually the chances are that no satisfactory water supply can be obtained in this way, unless the wells are bored to a sufficient depth to penetrate the artesian or Dakota sandstone. Water obtained in shale usually has a salty, disagreeable taste, being heavily laden with soluble salts.

A number of artesian wells have been drilled in the territory between Litchville and Ft. Ransom, at depths varying from 950 to 1,150 feet. Some of these exert a pressure as high as seventy pounds per square inch at the surface of the ground, and furnish an abundance of water valuable for general purposes. It is safe to say that these artesian wells may be secured on any portion of the Eckelson quadrangle, although the pressure may be rather weak in the higher areas near the northern part of the quadrangle.

Springs furnish a constant supply of good water from outcrops along the banks, and in ravines and coulees along the Sheyenne and

James valleys. These springs usually occur at some point where the valley has been cut into shale, the shale forming an impervious layer on which the water collects in sufficiently large quantities to escape as a spring. This is especially obvious in the Sheyenne valley.

ECKLESON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 14	Valley, NW 21	26	23	Sand and gravel all way
1, 14	NW. 21	30	27	Sand and gravel all the way
1, 29	Litchville, section 4	15	5	Surface loam and yellow clay
1, 29	Section 4	28	25	Surface loam and yellow clay
1, 29	NW. 10	20	17	Sandy yellow clay
1, 29	Section 10	40	30	
1, 29	Section 10	25	19	
1, 30	Section 2	20	15	Yellow clay, quicksand. blue clay
1, 30	Oakville, NW. 30	9	8	Gravel and sand to blue clay
1, 30	Spring Creek, SE. 24	13	4	11 ft. yellow clay
1, 31	NE. 24	25	13	Yellow clay
1, 31	Section 22	8	5	Yellow clay
1, 31	Section 22	29	25	Yellow clay
1, 31	Section 26	22	12	Yellow clay
1, 32	Section 22	36	18	10 ft. yellow; 13 ft. blue; sandy blue clay
1, 32	Prairie, NW. 14	82	72	20 ft. yellow; 20 ft. blue; 5 ft. sand; 37 ft. blue clay
1, 32	NW. 14	42	37	20 ft. yellow; 20 ft. blue sand
1, 32	NE. 14	32	22	20 yellow; 18 ft. blue gravel
1, 33	NE. 14	42	30	20 ft. yellow; 20 ft. blue gravel
1, 33	Prairie, SW. 14	32	26	25 ft. yellow; 6 ft. dark yellow material in chunks with vertical cracks
1, 33	SE. 14	30	18	Yellow clay, blue sand
1, 33	S. 22	40	36	30 ft. yellow; 5 ft. blue; 13 quicksand
1, 34	SE. 10	150	No water	35 ft. yellow; 60 ft. blue; 8 ft. sand shale; deposit to shales 103 ft.
1, 34	S. 23	30	24	Yellow and blue clay
1, 34	S. 23	16	4	Blue clay to quicksand
1, 35	S. 22	45	43	30 ft. yellow clay; 6 ft. gray sand
1, 35	S. 26	37	35	Yellow clay and sand (quicksand)
1, 35	S. 26	40	37	Yellow clay to sand
1, 35	(Griswold) S. 27	28	25	Yellow sandy clay
1, 36	S. 26	42	36	32 ft. yellow; 6 ft. blue hardpan
1, 36	S. 27	36	34	26 ft. yellow; 7 ft. blue; 3 inches hardpan
1, 36	NE. 34	42	40	38 ft. yellow clay; 4 ft. quicksand
1, 36	Gladstone, NW. 2	38	36	32 ft. yellow clay; 5 ft. sand
1, 36	SW. 2	30	27	20 ft. yellow; 10 ft. blue-gray sand
1, 37	SE. 2	28	22	18 ft. yellow; 6 ft. blue
1, 37	Gladstone, NW. 12	40	30	18 ft. yellow (hard); 2 ft. dry sand; 3 ft. quicksand; 15 ft. blue clay
1, 38	Prairie, SE. 36	38	32	
1, 38	SW. 24	45	35	Yellow clay, quicksand, blue clay
1, 38	SW. 26	15	12	Blue clay
1, 34	SW. 24	100	No water	Shale at 80 ft.
1, 38	NW. 12	45	40	7 ft. yellow; 18 ft. blue gravel veins; blue clay
1, 39	SW. 12	30	26	32 ft. yellow; 7 ft. blue-yellow sand
1, 39	S. 12	32	28	
1, 40	T. 139, R. 58, NW¼ 6	34	24	Yellow clay and veins of sand
1, 41	NE. 6	140	50	Some shale at 30 ft.
1, 42	SW. 6	21	15	Sand and gravel
1, 43	Greene, NE. 12	38	32	Yellow and blue clay
1, 43	SW. 1	28	20	
1, 46	Greene, SE. 10	22	8	Yellow clay and gravel
1, 47	NE. 10	29	26	Gravelly yellow clay, hardpan
1, 48	NW. 11	14	10	7 ft. black loam; 10 inches white clay; hard, yellow clay

SHEET

Bottom	Character of Water	Supply	Character of Surface	Remarks
Sand & gravel	Nearly soft..	Good	Valley slope.	NW. corner of Valley City.
Sand & gravel	Nearly soft..	Fair	Valley slope.	NW. corner of Valley City.
Sand..........	Nearly soft..	Good.		
....	Hard, good..	Good	Level.	
Quicksand ...	Hard.........	Poor.		
....	Hard.........	Good	....	Dug 60 ft. in blue clay.
....	Soft.........	Good.		
Blue clay.....	Hard.........	Poor.		
Blue clay.....	Soft..........	Good	NW edge of S. Prairie..	
Quicksand ...	Hard.........	Good	Foot of Sand Prairie hill.	Wells alike one half mile apart.
Quicksand ...	Hard.........	Good	In Maple hills......	
Gravel.......	Soft, good...	Good	Ravine	Boulders many.
Gravel.......	Soft, good.			
Sand, blue clay	....	....	....	Blue clay at 22 feet.
Sandy blue clay.........	Nearly soft..	....	....	Clay more sandy with depth.
Blue clay.....	Salty	....	....	May be shale in bottom.
Sand	Alkaline.....	....	....	All close together.
Gravel........	Hard.........	....	....	
Gravel........	....	....	....	
Coarse sand..	Hard.........	....	....	Material in bottom shale like
Quicksand over blue clay.........	Hard-........	....	....	Quicksand rather coarser than usual and mixed with gray soil.
Blue clay.....	....	....	....	Claimed to be northern edge of quicksand belt.
Shale.........	Salty	....	....	Shale alternated with 10 inches hard material and 7 or 8 ft. is softer and lighter.
Quicksand ...	Soft..........	....	....	½ mile apart.
Quicksand ...	Soft..........	....	....	In ravine (east).
Quicksand ...	Hard	....	....	Quicksand under coarser sand.
Quicksand ...	Hard.........	....	....	Believe quicksand would be found in 40 ft. well if dug deeper; wells close together.
Sand	Hard.........	....	....	
Quicksand (white).....	Hard.			
Quicksand ...	Hard.........	....	....	Griswold P. O.
Quicksand ...	Hard.			
Quicksand ...	Hard.			
Coarse brown sand........	Hard.			
Quicksand ...	Soft, good.			
Quicksand ...	Hard.			
Gravel and blue clay....	....	....	....	Considerable water in the quicksand.
Quicksand ...	Hard, good.			
Blue clay.....	Hard	....	....	Quicksand vein very thin.
Quicksand.				
Shale.				
Blue clay.....	Hard; alkali.			
Sand (yellow gravel	Hard.			
Blue clay.				
Clay....	Very hard...	....	....	Blue clay at 60 ft. here.
Shale.........	Salty	....	....	Tastes like artesian water.
....	Hard.			
....	Hard.			
....	Slightly hard			
Gravel........	Hard	Poor.....	Side hill.....	Side of Maple Ridge.
Sand.........	Hard	Good	Maple hill...	
Yellow cla ..	Limelike, bitter.........	Poor.....	Gravel valley	

ECKLESON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 49	SW. 2	32	29	Gravel to sand
1, 50	NE. 11	25	21	Loam and yellow clay, 5 ft.; grayel, 5 ft.; blue clay, 15 ft
1, 51	NE. 2	20	17	Yellow clay to gravel and sand
1, 53	139, 58, section 8	21	11	15 ft. yellow clay, sand and gravel
1, 53	Section 8	42	38	15 ft. yellow clay, sand, blue clay, hardpan
1, 55	139, 58, section 7	50	16	10 ft. yellow; 40 ft. blue
1, 56	Section 18	30	54	25 ft. yellow and blue clay shale
1, 57	Section 29	60	....	Yellow and blue clay
1, 58	Section 32	200	....	....
1, 58	Oakville, section 7	22	14	Yellow clay and gravel
1, 59	Section 7	18	8	Yellow clay and small stones
1, 59	Spring Creek, Sec.12	70	....	10 ft. yellow clay; 60 ft. blue clay
1, 60	Section 28	30	24	15 ft. yellow clay; 15 ft. blue clay
1, 60	Spring Creek, Sec. 20	40	Little wat'r	Yellow and blue clay
1, 62	Oakville, SW. 29	15-13.5	14-11-3	Gravel all way
1, 63	Oakville, Sec. 20	33-27	31-25	Yellow clay; gravel
1, 63	Oakville, Sec. 28	30	27	Yellow, stony clay
1, 64	Oakville, center of E. ½ of section 28	60	58	Yellow and blue clay 20 ft.; gray sand 40 ft
1, 65	Oakville, section 32	19	17	Gravel and sand
1, 65	Oakville, section 34	24	22	Gravel and sand
1, 66	Bear Creek, Sec. 6	14	12	Gravel and sand
1, 67	Bear Creek, Sec. 8	8	6	Gravel and sand
1, 67	Bear Creek, NW. section 17	7	5	3 ft. soil and clay; 4 ft. sand
1, 67	Bear Creek, Sec. 18	8	6	3 ft. soil and clay; 5 ft. sand
1, 68	Ft. Ransom, Sec. 18	24	20	3 ft. soil and clay; 14 ft. gravel; 7 ft. blue clay
1, 68	NE. section 18	12	10	2 ft. soil (upper); 4 ft. sand blue clay
1, 70	Black loam, Sec. 13	30	26	Yellow and some blue clay
1, 70	Ft. Ransom, Sec. 18	15	10	Sand and gravel
1, 71	Ft. Ransom, Sec. 7	32	16	Yellow bluish sand and blue clay
1, 71	Ft. Ransom, Sec. 8	11	7	2½ ft. loam; 7½ ft. yellow clay; 6 in. shale
1, 72	Ft. Ransom, Sec. 5	12	10½	2 ft. loam; yellow, sandy clay
1, 72	Bear Creek, Sec. 32	12	10	Gravelly sand
1, 73	Black loam, Sec. 1	46	25	19 ft. yellow clay; 21 ft. dry sand; 6 ft. chalk-like clay
1, 73	Ft. Ransom, Sec. 6	30	20	Dug in clay and shale
1, 74	Bear Creek, Sec. 30	36	No water	Dug in hard blue clay
1, 74	Litchville, section 24	15	9	Red sand, quicksand
1, 75	Bear Creek, Sec. 19	158	No water	4 ft. sand; 2 ft. clay; 32 ft. blue shale; 42 ft. white shale (chalkstone); 78 ft. soft blue shale
1, 75	Litchville, section 24	39	24	3 ft. yellow clay; 36 ft. blue clay; quicksand
1, 76	Litchville, section 12	34	14	12 ft. yellow clay; 22 ft. blue clay; yellow, blue sand
1, 76	Litchville, section 2	73	57	10 ft. yellow clay; 60 ft. blue clay; gravel
1, 77	Oakville, setion 31	7	5	Gravel and sand
1, 79	Lincoln, section 25	48	46	10 ft. yellow clay; 38 ft. blue; boulders and gravel
1, 79	Lincoln, section 25	80	50	20 ft. yellow; 30 ft. blue gravel and sand; 30 ft. blue clay
1, 80	Lincoln, section 25	127	120	15 ft. yellow clay, 25 ft. blue clay; sand vein; 60 ft. blue clay; shale

SHEET—Continued.

Bottom	Character of Water	Supply	Character of Surface	Remarks
Sand	Slightly hard	Good	On Maple hill	Valley bottom marshy; sand prairie at foot of hills.
Quicksand	Hard	Poor	On hill	Numerous springs in valley below.
Blue clay	Hard	Good	Side hill.	
Blue clay	Alkaline, h'rd			
Sand	Hard, alk'line	Good	...	Slaty hardpan at 40 ft.
Quicksand	Hard, alk'line	Fair	Valley bottom.	
Shale	Bitter, salty, alkaline	...	Lowandlevel	Shale in sight here at depth of probably 25 ft.
...	Very bitter, alkaline	...	Low	May be shale in this well.
Shale	No water			
Gravel & sand	Hard	Fair	Slope.	
Gravel	Soft	Good.		
Sandy clay	Hard, alk'line	Poor.		
Quicksand	Slightly hard	Fair	High ground	
Blue clay, some gravel	Hard, alk'line	Poor	Low prairie.	
Gravel	Nearly soft	Good	High prairie.	
Black sand	Hard	...	Foot of hill	Wells quarter mile apart.
Gravel, sand.	Soft	Good	Foot of small ridge.	
Sand	Soft	Strong, good	On hill north of sand prairie	Northern edge of sand prairie.
Sand	Nearly soft	Good	Very level, low	Sand prairie region.
Sand	Nearly soft	Good	Level, low	Sand prairie.
Sand, gravel	Nearly soft	Good	Level, low	Sand prairie.
Sand, gravel	Nearly soft	Good	Level, low	Sand prairie.
Sand	Nearly soft	Good	Level, low	Sand prairie.
Sand	Nearly soft	Good	Level, low	Sand prairie.
Sandy gravel.	Hard	Poor	Slightly rolling prairie.	
Sand	Good, muddy	Fair	Level prairie	Clay, gravelly.
Sand, gravel	Nearly soft	Fair	Level prairie	
Blue clay	Poor, alk'line	...	...	Clay, stony.
4 ft. quicks'nd	Nearly soft	Good	Level	Ft. Ransom hill toward east.
Quicksand	Nearly soft	Good	Level.	
Quicksand	Good, nearly soft	Good	Low level.	
Chalklike clay	Good, nearly soft	Fair	Low level	Probably shale at 40 feet.
Shale	Salty	Poor	Low level	Shale in bottom.
...	...	...	...	May be shale in bottom.
Quicksand	Fairly soft	Comes in fast	Rolling prairie.	
Blue clay	...	...	Nearly level prairie.	
Quicksand	Hard	Comes in fast	...	Water in other wells salty.
Yellow, blue sand	...	...	On hill.	
Gravel vein	Good, hard.			
Gravel	Good	Comes in fast	Level	Sand prairie.
Stones, gravel	Hard, alk'line	Poor	Nearly level.	Litchville City.
Gravel, sand.	Hard, alk'line	Poor	Level	Litchville City.
Shale	Hard, alk'ne	Poor	Level	Litchville City.

ECKELSON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 81	Scandia, S. 20.......	32	28	20 feet loam and clay (yellow), 6 feet gravel, 3 feet blue clay..............
1, 82	Scandia, S. 8........	18	13	Yellow clay and gravel................
1, 82	Scandia, S. 5........	61	36	27 ft. yellow clay, 34 ft. blue clay....
1, 83	Green, S. 28.........	28	25	2 ft. black loam, 3 ft. yellow. 23 ft. yellow clay............................
1, 84	Green, S, 22.........	20	18	2 ft. soil, 18 ft. yellow clay............
1, 85	Sp. Creek, S. 2......	12	6	Yellow clay..........................
1, 86	Sp. Creek, S. 20.....	45	15	6 ft. yellow, 35 ft. blue clay with sand streak, hard pan....................
1, 88	Sp. Creek, S. 32.....	65	....	Yellow and blue clay to shale (at 60 ft.)
1, 88	Litchville, S. 7......	20	18	Yellow clay, gravel and sand..........
1, 89	Litchville, S. 8......	92	42	20 ft. yellow clay, 40 ft. blue clay, shale and blue clay ....
1, 90	Litchville, S. 18.....	90	....	15 ft. yellow clay, 45 ft. blue clay, shale [clay(?)] ....
1, 92	Litchville, S. 20.....	27	21	8 ft. yellow clay. 19 ft. blue clay, quicksand in bottom......................
1, 93	Litchville, SW. 30..	85	....	6 ft. yellow, 25 ft blue, gravel and sand, blue clay...........................
1, 93	Litchville, SW. 30..	120	115	30 ft. yellow, 40 ft. blue, 50 ft. blue shale
1, 94	Litchville, NE. 28..	45	25	15 ft. sand, 30 ft. gravel and clay, hard pan............................
1, 95	Litchville, SE. 27...	19	9	12 ft. coarse gravel, 7 ft. gravelly blue clay ....
1, 97	Black loam, SE. 4..	42	32	15 ft. yellow clay, 27 ft. blue clay......
1, 99	Prairie, SW. 2.......	60	....	20 ft. yellow clay, 3 ft. dry sand, 36 ft. blue clay..........................
1, 100	Lincoln, NW. 32....	35	33	Yellow and blue clay..................
2, 1	Gladstone, NW. 4...	22	18	Yellow and blue clay..................
2, 1	Black loam, SW. 18.	30	20	15 ft. yellow clay, 15 ft. blue clay......
2, 2	Black loam, SW. 8..	49	44	Yellow and blue clay, (water at 30 ft. in sand)..............................
2, 3	Black loam, SW. 2..	24	20	23 ft. yellow clay, 1 ft. quicksand......
2, 4	Black loam, NE. 3..	20	....	Shale at 20 feet ....
2, 5	Prairie, SW. 10......	57	42	20 ft yellow clay, 12 ft hard blue, 25 ft. sandy blue..........................
2, 6	Prairie, NW. 28.....	45	41	Sandy clay for 40 ft, hard pan, sand...
2, 7	Prairie, SW. 28.....	46	44	35 ft. yellow clay, 16 ft. blue clay, quicksand............................
2, 8	Prairie, NW, 34.....	30	15	Layers of yellow clay, gravel, sand, black gumbo, etc....................

SHEET—Continued

Bottom	Character of Water	Supply	Character of Surface	Remarks
Quicksand	Hard	Very g'd	...	Boulders numerous.
Sand & gravel	Soft	Good	Edge of glacial slough.	
Sandy blue clay	Hard	Fair		
Gravel & sand	Nearly soft	Very g'd	Edge of low flat	Surrouudings morainic. Water level in flat same.
Quicksand	Very hard	Good	Nearly level.	
Sand	Nearly soft	Very g'd	Near edge of slough.	
Gravel under hard pan	Salty	Poor.		
Blue shale				
Blue clay	Hard	Comes in fast	Near edge of creek.	
Shale	Soft, fairly good	Does not come in fast		
Shale	...	...	...	Claim shale was not struck until 90 feet was reached.
Quicksand	Hard.			
Shale	...	...	...	Considerable water in gravel and sand at 30 feet.
Shale	Hard, salty	Poor	On high mor. hill.	
Clay	Hard,alk'line	Fair		
Blue shale	Hard,alk'line	Fair	...	Shale here between 45-60 feet.
Quicksand	Hard.			
Gravelly blue clay	Very little water	...	...	Shale here at 100 feet.
Gravel	Hard, good	Comes in fast	High rolling prairie.	
Quicksand	Soft	Comes in fast	On hill	Surrounding morainic
Stone& gravel	Hard	Comes in fast	...	Quicksand in well close by at 38 feet.
Blue clay	Hard.			
Blue clay	...	V'ry poor	High	Shale in other well at 91 feet.
Shale	...	Poor	Near slough.	Have dug as deep as 57 feet and found little water.
Coarse grey blue sand	Hard	Comes in fast	High, rolling	
Quicksand	Hard	Comes in fast	High flat-topped hill.	
Quicksand	Hard	V'ry poor	...	Quicksand 12 ft. Blue clay under sand.
Quicksand	Hard	Comes in fast		

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